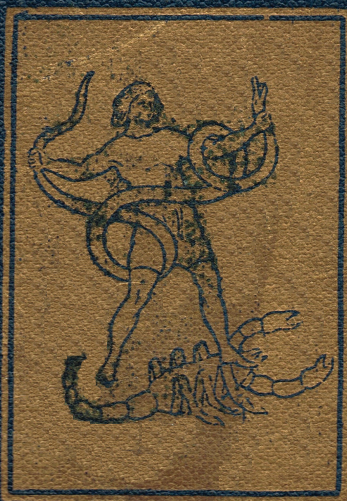
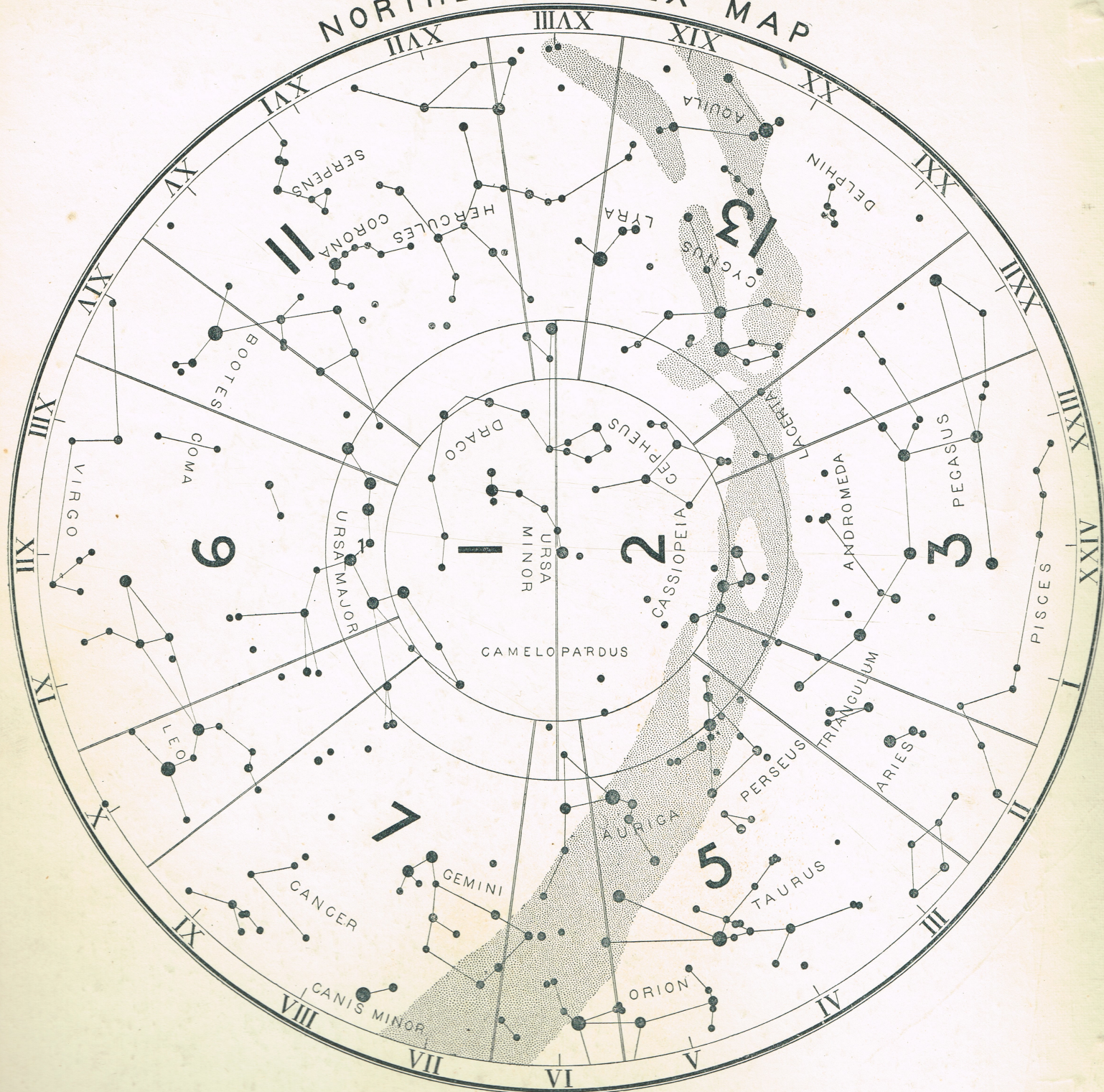


NORTON'S STAR ATLAS
AND TELESCOPIC HANDBOOK



7000 STARS, CLUSTERS, NEBULAE, &c.
FOR EPOCH 1920.

NORTHERN INDEX MAP



*Fifth Edition, Maps completely Revised,
with new I.A.U. Boundaries*

A S T A R A T L A S

AND REFERENCE HANDBOOK

(EPOCH 1920)

FOR STUDENTS AND AMATEURS

*Covering the whole Star Sphere, and showing over 8000 Stars, Nebulae,
and Clusters; with Short Descriptive Lists of Objects suitable
for Small Telescopes; Notes on Planets,
Star Nomenclature, &c.*

BY

ARTHUR P. NORTON, B.A.

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Made and printed in Great Britain

PREFATORY NOTE

THIS Atlas is primarily designed for those amateur telescopists whose instruments are mounted either on alt-azimuth stands or as equatorials without graduated circles. It is also intended to be used as a companion to Webb's invaluable "Celestial Objects for Common Telescopes," and Smith's admirable "Cycle of Celestial Objects." Practically all the objects contained in the latest editions of these two works, down to and including stars of the seventh magnitude, are shown in the maps, also several fainter objects of popular interest. For the occasional observer, selected lists of interesting objects are given, also notes on the Sun, Moon, Planets, &c.

Owing to the plan and arrangement of the maps, and also on account of the large overlap, a view of about one-fifth of the entire heavens is shown on one folio, and no constellation is inconveniently broken up. The distortion is slight considering the large area represented. Altogether the charts indicate the positions of nearly 8,000 stars and 600 nebulae (Fifth Edition) for the epoch 1920—the same as that adopted in the latest edition of "Webb."

A sketch Map of the Moon, indicating the more important features, and two charts of the Galactic regions, are provided; the latter, having R.A. and Dec. lines as well as galactic co-ordinates, will be helpful in galactic studies.

Variable and red stars are indicated by "V" and "R" respectively, but double stars could not be similarly lettered without sacrificing the clearness of the maps; refer to the lists in "Webb," &c.

As an introduction to the present work, the beginner is recommended to procure that very useful little book, Gall's "Easy Guide to the Constellations" (*Gall & Inglis*); by its aid he will learn to recognise the more important constellations and their relative positions, and to understand their apparent daily motions.

The Reference Handbook, at the beginning of the volume, is divided into five sections. The first four give short popular explanations of various astronomical terms met with in current astronomical literature, almanacs, &c., and short descriptions of celestial objects and phenomena. The underlying idea has been to furnish both the amateur observer and the general reader with a reference book, to which he can turn for an explanation of unfamiliar terms—observational terminology especially being very inadequately dealt with in text-books.

The fifth and sixth sections are devoted to the needs of the observer—the most favourable observing seasons for various classes of objects; how to use and care for the telescope; useful tables, &c.

Owing to the limited space available, these explanations are necessarily much compressed, but it is hoped they are sufficiently complete for the required purpose. Sources of fuller information are often given.

For most of the additional notes and tables I am greatly indebted to Mr J. Gall Inglis, who has collaborated with me from the first. Thanks are also due to Mr Gavin J. Burns, Dr L. J. Comrie, Mr Peter Doig, M. Felix de Roy, and other gentlemen, who very kindly revised proofs and furnished information that was not readily obtainable; to the International Astronomical Union, for permission to use various extracts from the *Transactions*, and to Mr W. F. Denning, who very obligingly favoured me with an improved list of meteor radiants.

Very great pains have been taken to make the maps correct; but the writer will be grateful to anyone who, having detected an error, will kindly communicate with him. [*1st Edition 1910, and later issues.*]

PREFACE TO THE FIFTH EDITION.

In 1930, the International Astronomical Union adopted the scheme of constellation boundaries prepared by Mons. E. Delporte, thus fixing them definitely and unchangeably for the first time since the constellations were invented. The author was at last placed in a position to carry out a long-desired and thorough revision of his maps, and in this Fifth Edition he offers the result of a congenial, though long and rather laborious undertaking. In the revised Charts:—

- (a) The constellation boundaries have been redrawn in accordance with the International Astronomical Union's scheme.
- (b) The star discs are now drawn to indicate half-magnitudes, so as to give a better representation of the heavens.
- (c) Some 1500 additional objects have been added, and the charts now show practically all stars down to about mag. 6.2.
- (d) The Galactic Equator, Galactic Poles, and Milky Way (limits approximate), have been inserted.
- (e) The nomenclature and magnitudes, in general, are now those of the Revised Harvard Photometry, as being the most convenient standard of reference: previous Editions followed the Brit. Assn. Catalogue nomenclature, as a rule.

As the epoch of this Atlas is 1920, and that of Mons. Delporte's 1875 (see page 2), the constellation boundaries in the two works do not occupy precisely the same positions in R.A. and Dec.—the effect of precession in the 45 intervening years. The positions of the boundaries with respect to the stars themselves, however, remain unaltered.

The letterpress also has been thoroughly revised, and a list giving the pronunciation of constellation and star names has been added on page 51, in response to several requests.

Thanks are due to Sir A. Eddington for the note on Bolometric Magnitude, and to Dr. E. A. Baker for revising the paragraphs on Spectroscopy.

ARTHUR P. NORTON

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Time between a Star's rising and setting, and its culmination, or its semi-diurnal arc (approx.: refraction not allowed for). Observers in the N. Hemisphere read the star's N. or S. Dec. at the top of the column; those in the S. Hemisphere, at the foot.

N. Hemisphere:—STARS WITH NORTH DECLINATION.										N. Hemisphere:—STARS WITH S. DECLINATION.									
Observ.	30°	25°	20°	15°	10°	5°	0°	Observ.	5°	10°	15°	20°	25°	30°	Observ.	5°	10°	15°	20°
Lat.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	Lat.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	Lat.	h. m.	h. m.	h. m.	h. m.
5°	6 11	6 8	6 7	6 5	6 4	6 2	6 0	5°	5 58	5 56	5 55	5 53	5 52	5 49	5°	5 58	5 56	5 55	5 53
10	6 23	6 19	6 15	6 11	6 7	6 4	6 0	10	5 56	5 53	5 49	5 45	5 41	5 37	10	5 56	5 53	5 49	5 45
15	6 36	6 29	6 22	6 16	6 11	6 5	6 0	15	5 55	5 49	5 44	5 38	5 31	5 24	15	5 55	5 49	5 44	5 38
20	6 49	6 39	6 30	6 22	6 15	6 7	6 0	20	5 53	5 45	5 38	5 30	5 21	5 11	20	5 53	5 45	5 38	5 30
25	7 2	6 49	6 39	6 29	6 19	6 9	6 0	25	5 51	5 41	5 31	5 21	5 11	4 58	25	5 51	5 41	5 31	5 21
30	7 19	7 2	6 49	6 36	6 23	6 12	6 0	30	5 48	5 37	5 24	5 11	4 58	4 41	30	5 48	5 37	5 24	5 11
35	7 35	7 16	6 59	6 43	6 28	6 14	6 0	35	5 46	5 32	5 17	5 1	4 44	4 25	35	5 46	5 32	5 17	5 1
40	7 55	7 32	7 11	6 52	6 34	6 17	6 0	40	5 43	5 26	5 8	4 49	4 28	4 5	40	5 43	5 26	5 8	4 49
45	8 18	7 51	7 25	7 2	6 41	6 20	6 0	45	5 40	5 19	4 58	4 35	4 9	3 42	45	5 40	5 19	4 58	4 35
50	8 53	8 15	7 43	7 14	6 49	6 24	6 0	50	5 36	5 11	4 46	4 17	3 45	3 7	50	5 36	5 11	4 46	4 17
55	9 39	8 47	8 5	7 30	6 58	6 29	6 0	55	5 31	5 2	4 30	3 55	3 13	2 21	55	5 31	5 2	4 30	3 55
60°	11 22	9 35	8 36	7 51	7 11	6 35	6 0	60°	5 25	4 49	4 9	3 24	2 25	0 38	60°	5 25	4 49	4 9	3 24

S. Hemisphere:—STARS with SOUTH DECLINATION.

S. Hemisphere:—STARS with N. DECLINATION.

Magnitudes and Relative Brightness of the Sun, Planets, and Principal Stars, (1st magnitude star taken as 1·00).

Name of Star, &c.	H.R. Mag.	Brightness	Name of Star	H.R. Mag.	Relative Brightness	Name of Star	H.R. Mag.	Relative Brightness	Name of Star	H.R. Mag.	Relative Brightness
Sun ...	-26·6	{ 109,650 millions	Achernar ...	0·60	1·45	ε Canis Major.	1·63	0·56	δ Canis Major.	1·98	0·41
Moon (Full) ...	-12·2	190,550	β Centauri ...	0·86	1·14	ε Ursæ Major.	1·68	0·53	β Canis Major.	1·99	0·40
Venus (max.) ...	-4·28	129·4	Altair ...	0·89	1·11	γ Orionis ...	1·70	0·52	Magnitude	2·00	0·40
Jupiter* ...	-2·25	19·95	Betelgeuse ...	0·92	1·08	α ² Centauri ...	1·70	0·52	Polaris ...	2·12	0·36
Mars* ...	-2·25	19·95	Magnitude	1·00	1·00	λ Scorpii ...	1·71	0·52	Magnitude	2·50	0·25
Mercury (max) ...	-1·8	13·18	Aldebaran ...	1·06	0·95	ε Carinæ ...	1·74	0·51	" ...	3·00	0·16
Sirius ...	-1·58	10·77	Spica ...	1·21	0·82	ε Orionis ...	1·75	0·50	" ...	3·50	0·10
Saturn* ...	-0·93	5·92	Pollux ...	1·21	0·82	β Tauri ...	1·78	0·49	" ...	4·00	0·06
Canopus ...	-0·86	5·55	Antares ...	1·22	0·82	β Carinæ ...	1·80	0·48	" ...	4·50	0·04
Magnitude	0·00	2·51	Fomalhaut ...	1·29	0·77	α Triang. Aust.	1·88	0·44	" ...	5·00	0·03
Vega ...	0·14	2·21	Arieded ...	1·33	0·74	α Persei ...	1·90	0·44	" ...	5·50	0·02
Capella ...	0·21	2·07	Regulus ...	1·34	0·73	η Ursæ Major.	1·91	0·43	" ...	6·00	0·01
Arcturus ...	0·24	2·01	β Crucis ...	1·50	0·63	ζ Orionis ...	1·91	0·43	Uranus*	5·8	0·05
α ¹ Centauri	0·33	1·85	α ¹ Crucis ...	1·58	0·59	γ Geminorum	1·93	0·42	Magnitude	6·50	0·006
Rigel ...	0·34	1·84	Castor ...	1·58	0·59	ε Sagittarii ...	1·95	0·42	Neptune*	7·7	0·003
Procyon ...	0·48	1·61	γ Crucis ...	1·58	0·60	α Ursæ Major.	1·95	0·42	Pluto*	(14·5)	0·00002

Ratio of Brightness, fainter or brighter, for a difference in magnitude ("Diff.") of:—

Diff.	Ratio	Diff.	Ratio	Diff.	Ratio	Diff.	Ratio	Diff.	Ratio	Diff.	Ratio	Diff.	Ratio	Diff.	Ratio	Diff.	Ratio
0·1	1·10	0·5	1·58	0·9	2·29	1·3	3·31	1·75	5·01	3·0	15·85	5·5	158·49	8·0	1584·9	10·5	15,849
0·2	1·20	0·6	1·74	1·0	2·51	1·4	3·63	1·8	5·25	3·5	25·12	6·0	251·19	8·5	2511·9	11·0	25,119
0·25	1·26	0·7	1·91	1·1	2·75	1·5	3·98	1·9	5·75	4·0	39·81	6·5	398·11	9·0	3981·1	11·5	39,811
0·3	1·32	0·75	2·00	1·2	3·02	1·6	4·37	2·0	6·31	4·5	63·10	7·0	630·96	9·5	6309·6	12·0	63,096
0·4	1·45	0·8	2·09	1·25	3·16	1·7	4·79	2·5	10·00	5·0	100·00	7·5	1000·00	10·0	10,000·0	12·5	100,000

Distance and Magnitude:—Increase of distance ("Dist.") for a difference ("Diff.") of 1 to 20 magnitudes. Thus a Mag. 5 star placed 100 times further away would be 10 magnitudes fainter, or Mag. 15. (Mag.-diff. × 0·2 = logarithm of distance-increase).

Diff.	Dist.	Diff.	Dist.	Diff.	Dist.	Diff.	Dist.	Diff.	Dist.	Diff.	Dist.	Diff.	Dist.	Diff.	Dist.	Diff.	Dist.
½	1·26	2	2·51	4	6·31	6	15·85	8	39·81	10	100·0	12	251·2	14	631·0	16	1585
1	1·59	3	3·98	5	10·00	7	25·12	9	63·10	11	158·5	13	398·1	15	1000	17	2512
																18½	5012
																19½	7943
																20	10000

Mean Refraction (*Bessel*).—For 50° F. (10° C.), and barometer 29·6 ins. (752 mm). Other Temperatures, add 1% per 5° F. (2·8° C.) if lower, deduct if higher: Pressures, add 3½% per inch (25·4 mm.) if higher, deduct if lower; = abt. 1% $\frac{1}{4}$ inch, or $\frac{1}{8}$ mm.

Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.	Alt. Refraction.
0°	34' 54"	3°	26' 35"	6°	14' 15"	9°	8' 23"	12°	4' 25"	15°	3' 32"	25°	2' 3"	40°	1' 9"	65°	0' 27"
¼	31 50	1	24 25	4	11 39	7	7 20	10	5 16	13	4 5	16	3 19	30	1 40	45	0 58
½	29 3	2	18 9	5	9 47	8	6 30	11	4 49	14	3 47	20	2 37	35	1 22	50	0 48

Kilometres converted into Miles.—For multiples by 10, 100, or 1000, move decimal point one, two, or three places to right.

km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles	km. = miles
1	0·621	6	3·728	11	6·835	16	9·942	21	13·049	26	16·156	31	19·263	36	22·369	41	25·476
2	1·243	7	4·350	12	7·456	17	10·563	22	13·670	27	16·777	32	19·884	37	22·991	42	26·098
3	1·864	8	4·971	13	8·078	18	11·185	23	14·292	28	17·398	33	20·505	38	23·612	43	26·719
4	2·485	9	5·592	14	8·699	19	11·806	24	14·913	29	18·020	34	21·127	39	24·233	44	27·340
5	3·107	10	6·214	15	9·321	20	12·427	25	15·534	30	18·641	35	21·748	40	24·855	45	27·962

Parsecs and Light-years equivalent to any parallax (π). ·0001, ·0002, &c., move parsec or light-yr. decimal one place to rt.

π	Parsecs	Light-ys.	π	Parsecs	Light-ys.	π	Parsecs	Light-ys.	π	Parsecs	Light-ys.	π	Parsecs	Light-ys.	π	Parsecs	Light-ys.
·001"	1000	3259·0	·021"	47·62	155·19	·041"	24·39	79·49	·061"	16·39	53·43	·081"	12·35	40·24	·12"	8·33	27·16
·002	500·0	1629·5	·022	45·45	148·14	·042	23·81	77·61	·062	16·13	52·57	·082	12·20	39·75	·14	7·14	23·28
·003	333·3	1086·3	·023	43·48	141·69	·043	23·26	75·79	·063	15·87	51·74	·083	12·05	39·26	·15	6·67	21·73
·004	250·0	814·74	·024	41·67	135·79	·044	22·73	74·06	·064	15·63	50·92	·084	11·90	38·80	·16	6·25	20·37
·005	200·0	651·79	·025	40·00	130·36	·045	22·22	72·43	·065	15·38	50·14	·085	11·76	38·34	·18	5·56	18·11
·006	166·7	543·16	·026	38·46	125·35	·046	21·74	70·84	·066	15·15	49·39	·086	11·63	37·90	·20	5·00	16·30
·007	142·9	465·56	·027	37·04	120·70	·047	21·28	69·34	·067	14·93	48·64	·087	11·49	37·46	·22	4·55	14·81
·008	125·0	407·37	·028	35·71	116·39	·048	20·83	67·91	·068	14·71	47·93	·088	11·36	37·03	·24	4·17	13·58
·009	111·1	362·11	·029	34·48	112·38	·049	20·41	66·51	·069	14·49	47·24	·089	11·24	36·62	·25	4·00	13·04
·010	100·0	325·90	·030	33·33	108·63	·050	20·00	65·18	·070	14·29	46·56	·090	11·11	36·21	·26	3·85	12·54
·011	90·91	296·27	·031	32·26	105·13	·051	19·61	63·90	·071	14·08	45·90	·091	10·99	35·82	·28	3·57	11·64
·012	83·33	271·58	·032	31·25	101·84	·052	19·23	62·68	·072	13·89	45·27	·092	10·87	35·42	·30	3·33	10·86
·013	76·92	250·69	·033	30·30	98·76	·053	18·87	61·49	·073	13·70	44·65	·093	10·75	35·04	·35	2·86	9·31
·014	7·143	232·79	·034	29·41	95·85	·054	18·52	60·35	·074	13·51	44·04	·094	10·64	34·67	·40	2·50	8·15
·015	66·67	217·27	·035	28·57	93·11	·055	18·18	59·25	·075	13·33	43·45	·095	10·53	34·31	·45	2·22	7·24
·016	62·50	203·69	·036	27·78	90·53	·056	17·86	58·20	·076	13·16	42·88	·096	10·42	33·95	·50	2·00	6·52
·017	58·82	191·70	·037	27·03	88·08	·057	17·54	57·17	·077	12·99	42·33	·097	10·31	33·60	·55	1·82	5·92
·018	55·56	181·05	·038	26·32	85·76	·058	17·24	56·20	·078	12·82	41·78	·098	10·20	33·26	·60	1·67	5·43
·019	52·63	171·53	·039	25·64	83·56	·059	16·95	55·23	·079	12·66	41·26	·099	10·10	32·92	·65	1·54	5·01
·020	50·00	162·95	·040	25·00	81·47	·060	16·62	54·32	·080	12·50	40·74	·100	10·00	32·59	·70	1·43	4·66
															·75	1·33	4·35

* Mean opposition magnitudes: star magnitudes only are from the H.R.

Angular Distances on the Star Sphere.—For rough estimates on the star sphere the following approximations are convenient; others can easily be made up from the star charts: the degrees are those of a 'great circle,' as of Declination, or those measured along the Celestial equator. The star sphere contains 41,253 square degrees.

$\frac{1}{2}^{\circ}$ = the angular diameter of the Moon (approx.).	$2\frac{1}{2}^{\circ}$ = α to β AQUILÆ; or α to δ RETICULI. (approx.).
$1\frac{1}{4}^{\circ}$ = δ to ϵ ORIONIS; or β to λ CRUCIS. „	4° = α to β CANIS MINORIS; or α to β CRUCIS. „
2° = α to γ AQUILÆ; or α to σ SCORPII. „	5° = α to β URSÆ MAJORIS; or α to β CENTAURI. „

Symbols of Elements.—*Al*, Aluminium; *C*, Carbon; *Ca*, Calcium; *Fe*, Iron; *H*, Hydrogen; *He*, Helium; *K*, Potassium; *Mg*, Magnesium; *N*, Nitrogen; *Na*, Sodium; *O*, Oxygen; *Rb*, Rubidium; *Si*, Silicon; *Sr*, Strontium; *Ti*, Titanium; *Zr*, Zirconium.

Astronomical Societies, Publications, &c.—Contractions commonly used. Standard contractions are now being prepared; first list of General Contractions, and those for Places, see Trans. I.A.U. 1928.

Publication, or Society.	Publication, or Society.	General.
A.A.S. American Astronomical Society.	H.C. Harvard Circular (Harv. C.).	An. Annals.
A.A.V.S.O. American Association of Variable Star	H.C.O. Harvard College Observatory.	App. Appendix.
A.E. American Ephemeris. [Observers.]	I.A.U. International Astronomical Union.	Ass. Association.
A.G. Astronomische Gesellschaft.	J. Journal. (prefixed to Society name, as <i>J.B.A.A.</i>).	B., <i>Bull.</i> Bulletin.
A.J. Astronomical Journal.	J.O. Journal des Observateurs.	Cat. Catalogue.
A.N. Astronomische Nachrichten.	L.O.B. Lick Observatory Bulletin (Lick B.)	Cir. Circular.
Ap.J. Astrophysical Journal.	M.N. Monthly Notices Royal Astron. Society.	Cont. Contributions.
A.S.P. Astronomical Society of the Pacific.	Mt.W. Mt. Wilson Observatory.	Edn. Edition.
B.A. British Association.	Nat. Nature.	I. International.
„ Bulletin Astronomique.	N.A. Nautical Almanac.	Inst. Institute.
B.A.A. British Astronomical Association.	Obs. The Observatory.	M., <i>Mem.</i> Memoirs.
B.A.N. Bulletin of the Ast. Inst. of the Netherlands.	P. Publications, Proceedings. (prefixed to Society	Mag. Magazine.
B.J. Berliner Jahrbuch.	P.A. Popular Astronomy. [name, as, <i>P.A.S.P.</i>).	O., <i>Obs.</i> Observatory.
B.S.A.F. Bulletin de la Société Astronomique de	Phil. Trans. Philosophical Transactions of the Royal	Pr. Proceedings.
C.O. Cincinnati Observatory. [France.]	R.A.S. Royal Astronomical Society. [Soc.]	P., <i>Pub.</i> Publications,
C.R. Comptes Rendus (Paris Acad. Sciences).	R.A.S.C. Royal Astronomical Society of Canada.	or Published.
C.T. Connaissance des Temps.	S.A. Scientific American.	R. Review.
E.B. Encyclopædia Britannica.	U.O.C. Union Observatory Circulars.	Rp. Report.
E.M. English Mechanic.	V.J.S. Vierteljahrsschrift der Astron. Gesellschaft.	S., <i>Soc.</i> Society.
H.A. Harvard Observatory Annals.		S. Smithsonian.
H.B. Harvard Bulletin.		Tr. Transactions.
		Vol. Volume.
		Yb. Yearbook.

Astronomical Catalogues.—Contractions in ordinary use.

Contraction.	With number added, = Number in : —	Contraction.	With number added, = Number in : —
A.G. Astronomische Gesellschaft, Catalogues of the (see p. 39).		H.D. Henry Draper Cat. 1918-24 (vols. 91-99, Harvard Annals).	
A.G.C. Sometimes used for A.G. Also = C.G.A.		H.P. Harvard Photometry (<i>Pickering</i>), 1884. (<i>H.A.</i> vol. 14).	
(Arg.) Argelander. (See B.D. below).		H.R. (also 'R.H.P.'). Revised Harvard Photometry, 1908. (Vol.	
(B) Birmingham's Catalogue of Red Stars, 1877. (See E-B.)		(Jac.) Jacob's Catalogue of Double Stars, 1848. [50 of <i>H.A.</i>).	
B (In <i>Nautical Almanac</i>) Bode's Catalogue, 1801.		(Lac.) Lacaille's Catalogue of Southern Stars, Epoch 1750,	
B.A.C. British Association Catalogue, epoch 1850 (<i>Baily</i> , 1845).		published by the British Association, 1847.	
B.D. Bonn Durchmusterung (<i>Argelander</i>) to mag. 9, 1859-62, +		Ll. or Lal. Lalande's Cat., Epoch 1800, pub. by the B.A., 1837.	
2° to 23° South Dec., extended by Schönfield (1886).		M. Messier's Catalogue of 103 Nebulæ & Clusters, pub. 1784.	
β Burnham's Double Star Catalogues (not his General Cat.,		Reprinted, <i>Obs.</i> , Aug. 1918; and <i>P.A.S.P.</i> Aug. 1917.	
B.G.C. Burnham's General Cat. of Double Stars. [B.G.C.])		N.G.C. New General Catalogue (of Sir J. Herschel's Nebulæ and	
Br. Auwer's reduction of Bradley's Observations.		Clusters, <i>Dreyer</i>), 1888. Vol. 49, Memoirs, R.A.S.	
(Bris. or Br.) Sir T. Brisbane's Catalogue of Southern Stars, 1835.		O.A. Oeltzen's reduction of Argelander's Zone Observations.	
C.D. Cordoba Durchmusterung, 22° to 62° S. [(<i>Gould</i>) 1886.		P.D. Potsdam General Cat. (Supplementary vols.) P.P.D., &c.	
C.G.A. Catalogo General Argentino, 32,448 Southern Stars,		P.G.C. Preliminary General Catalogue of 6188 stars (<i>Boss</i>), 1910.	
C.P.D. Cape Photographic Durchmusterung, to mag. 9, 19° to		ph. Great International Photographic Star Map.	
90° South Dec. (<i>Gill and Kapteyn</i>), 1896-1903.*		Pi. Piazzi's Star Cat., epoch 1800, 1803-14. Nos. in hrs. of R.A.	
C.Z. Cordoba Zone Cat. of South Stars, Nos. in zones of Dec. †		(Rus.) Russell's Double Star Measures (Sydney), 1891.	
(Δ) Dunlop's Catalogues of Double stars and Nebulæ, 1828.		(S.) South's Measures of Double Stars, 1826.	
(E-B.) Espin's edition of Birmingham's Cat. of Red Stars, 1888.		(Sa.) Santiago Observations, 1876.	
E.B.L. Eigenbewegungs Lexikon (<i>Hamburg Obs.</i>) of all known		(S.M.P.) Southern Meridian Photometry (Harvard), 1895.	
G (In Brit. Naut. Almanac) = U.A. [proper motions.		(St.) Stone's Cape Catalogue for 1880, or Radcliffe Cat., 1890.	
G.F.H. Geschichte des Fixsternhimmels, see p. 39. [Pub. 1838.		W.B. Weisse's reduction of Bessel's Zones, equinox 1825. Nos. in	
(Gr.) Groombridge's Catalogue of Circumpolar Stars for 1810,		W.Z.C. Washington Zodiacal Cat., 1900, 1920. [hrs. of R.A.	
H Sir W. Herschel's Catalogues of Double Stars, 1782-1822.		U.A. Uranometria Argentina (<i>Gould</i>), 1879.	
„ (In <i>Nautical Almanac</i>) Hevelius's Catalogue, 1660.		U.O. Uranometria Nova Oxoniensis (<i>Pritchard</i>), 1885.	
H' („ „) Heis' Catalogus Stellarum, 1872.		Z Wilhelm Struve's Dorpat Cat. of Double Stars, 1837.	
(Houz.) Houzeau's Uranométrie Générale, 1878.		ZI do. do. Appendix I.	
h Sir J. Herschel's Catalogues of (1) Nebulæ, 1833, 1847; and (2) of Double Stars.		OZ Otto Struve's Revised Pulkova Catalogue, 1850.	
		OZZ Pulkova Catalogue, Part II.	

* In this case the zone is stated as well as the number: thus B.D. + 13° 2302 means star No. 2302 in the 13° zone, north Dec., in the B.D.

† The numbering commences anew in each hour of R.A.: thus Vh 123 denotes star No. 123 in the zone of 5 h. R.A.

The Greek Alphabet.

Letter	Name	Letter	Name	Letter	Name	Letter	Name	Letter	Name	Letter	Name
α	Alpha ... A	ϵ	Epsilon ... E	ι	Iota ... I	ν	Nu ... N	ρ	Rho ... P	ϕ	Phi ... Φ
β	Beta ... B	ζ	Zeta ... Z	κ	Kappa ... K	ξ	Xi ... Ξ	σ	Sigma ... S	χ	Chi ... X
γ	Gamma ... Γ	η	Eta ... H	λ	Lambda ... Λ	$\omicron$	Omicron ... O	τ	Tau ... T	ψ	Psi ... Ψ
δ	Delta ... Δ	θ	Theta ... Θ	μ	Mu ... M	π	Pi ... Π	υ	Upsilon ... Y	ω	Omega ... Ω

Significance of + and -. Used for Direction. + indicates (a) northwards; (b) 'direct' or 'positive' motion, = to the left, or eastwards when looking south: - indicates (a) southwards; (b) 'retrograde' or 'negative' motion, = to the right, or westwards when looking south. **Used for Variable Stars,** + indicates that a maximum or minimum is later than the predicted date; -, that it is earlier. **Used for Comets** in same sense as for variables, to indicate departure from the ephemeris, or the elements. **Earth's Area, and Zenographic Dec.**—when +, the planet's North pole is presented to the Earth; when -, the South pole.

Declination: — + = North of celestial Eq. - = South " "	Libration: mean centre is:— + = Displaced to E. (longit.) - " " " W. "	Position Angle Sun's Axis: — + = N. Pole, E. } of the Hr. - = " " W. } Circle	Radial Velocity: — + = Recession from Sun - = Approach to " "
Latitude: — + = N. } of Ecliptic, or of - = S. } Earth's or Gal. eqr.	Libration: mean centre is:— + = Displaced to S. (lat.) - " " " N. "	Proper Motion, Precess'n (Dec.) + = Northwards, see note, - = Southwards [p. 39].	Saturn's Rings: — (p. 24). + = Earth N. of ring plane. - = " S. " "
Longitude: — + = W. } of Greenwich. - = E. }	Magnitude: — + = Fainter than mag. 0.0 - = Brighter " " 0.0	Proper Motion, Precess'n (R. A.) + = Direct, see note, p. 39. - = Retrograde.	Sun's Equator: — (p. 34). + = S. of centre of disc - = N. " "

Astronomical Signs or Symbols (occasionally-used symbols in brackets):—

Signs of the Zodiac.	Aries	Taurus	Gemini	Cancer	Leo	Virgo	Libra	Scorpio	Sagittarius	Capricornus	Aquarius	Pisces		
<i>Symbol.</i>	♈	♉	♊	♋	♌	♍	♎	♏	♐	♑	♒	♓		
Sun, &c.	Sun	Mercury	Venus	Earth	Moon	Mars	Minor planet	Jupiter	Saturn	Uranus	Neptune	Pluto	Comet	Star
<i>Symbol.</i>	☉ (○)	☿	♀	♁ (⊕)	☾	♂	♁	♃	♄	♅	♆	♇	☄	★
Other Signs.	Conjunction,	Quadrature,	Opposition.	Node (longitude of).	Moon's Phases:—				New,	1st qr.,	Full,	3rd qr.		
<i>Symbol.</i>	♌	☐	♋	♌ ascending	...				☀	☾	☉	☾		
	= Longit. from Sun, 0°	90°	180°	☾ descending	= Longit. from Sun				0°	90°	180°	270°		

Constellation Abbreviations. Three-letter contractions (Internat. Astronomical Union, 1922). (Malus replaced by Pyxis).

And Andromeda	Car Carina	CrB Corona Bor.	Gru Grus	Lyr Lyra	Phe Phoenix	Sgr Sagittarius
Ant Antlia	Cas Cassiopeia	Crt Crater	Her Hercules	(Malus = Pyxis)	Pic Pictor	Tau Taurus
Aps Apus	Cen Centaurus	Cru Crux	Hor Horologium	Men Mensa	PsA Piscis Aust.	Tel Telescop'm
Aql Aquila	Cep Cepheus	Crv Corvus	Hya Hydra	Mic Microscop'm	Psc Pisces	TrA Triang. Aus.
Aqr Aquarius	Cet Cetus	CVn Canes Ven.	Hyi Hydrus	Mon Monoceros	Pup Puppis	Tri Triangulum
Ara Ara	Cha Chamæleon	Cyg Cygnus	Ind Indus	Mus Musca	Pyx Pyxis	Tuc Tucana
Arg Argo	Cir Circinus	Del Delphinus	Lac Lacerta	Nor Norma	Ret Reticulum	UMa Ursa Major
Ari Aries	CMA Canis Maj.	Dor Dorado	Leo Leo	Oct Octans	Scl Sculptor	UMi Ursa Minor
Aur Auriga	CMi Canis Min.	Dra Draco	Lep Lepus	Oph Ophiuchus	Sco Scorpius	Vel Vela
Boo Boötes	Cnc Cancer	Equ Equuleus	Lib Libra	Ori Orion	Set Scutum	Vir Virgo
Cae Caelum	Col Columba	Eri Eridanus	LMi Leo Minor	Pav Pavo	Ser Serpens	Vol Volans
Cam Camelopard.	Com Coma Ber.	For Fornax	Lup Lupus	Peg Pegasus	Sex Sextans	Vul Vulpecula
Cap Capricornus	CrA Corona Aus.	Gem Gemini	Lyn Lynx	Per Perseus	Sge Sagitta	

Astronomical Contractions.—Those for Astronomical Societies and Publications, Star Catalogues, &c., are given on p. vii.

R	Right Ascension	G.M.N. Greenwich Mean Noon	Long. Longitude	S.A. Selected Areas
A.U.	Astronomical Unit; also	G.M.T. " " Time	Mag. Magnitude	S.D. Semi-diameter
	Angstrom Unit	H.I. Heat Index	N.P.D. North Polar Distance	U.T. Universal Time
C.M.	Central Meridian	H.P. Horizontal Parallax	N.P.S. " " Sequence	Z.D. Zenith Distance
Dec.	Declination	I.A. International Angstrom	O.-C. Observed—calculated	<i>nf</i> North following.
Eqr.	Equator	J.D. Julian Day, p. 7.	P.; P.A. Position Angle	<i>np</i> North preceding.
Gal.	Galactic	J.A.D. " Astr. Day, p. 7.	P.E. Probable Error	<i>sp</i> South preceding.
G.C.T.	Greenwich Civil Time	K. Kelvin (Abs. temp., p. 17).	P.M. Proper Motion	<i>sf</i> South following.
G.M.A.T.,	Mean Astron. Time	Lat. Latitude	R.A. Right Ascension	[h., hours; m., minutes; s., seconds.
				cm., centimetres; km., kilometres.

Astronomical Symbols.—See long list in British N.A., 1930 onwards.

α Right Ascension	ρ Terrestrial radius	d Distance, in seconds of arc	M Magnitude, absolute
β Latitude (celestial)	Σ (or []) symbol of summation	E Equation of time	<i>m</i> " apparent (visual)
δ Declination	ϕ Angle whose sine = eccentricity	<i>e</i> Eccentricity of orbit ²	<i>m_s</i> " photographic
Distance from Earth in A.U.	ϕ Geographical latitude	<i>g</i> Acceleration due to gravity	<i>m_{pv}</i> " photovisual
Δ Symbol for a small increment	ϕ' Geocentric latitude	G Galactic longitude	<i>m</i> Mass
ϵ Obliquity of Ecliptic	ω Argument of perihelion	<i>g</i> " latitude	<i>n</i> Mean motion (or μ)
λ Longitude.	ϖ Longitude of perihelion*	<i>h</i> Hour angle	P Period of revolution
λ Wave-length, in angstroms	Ω Longitude of ascending node	<i>i</i> Inclination of plane of orbit	<i>p</i> Position angle, 0°-360°
μ Proper motion	A Azimuth	<i>J</i> Surface brightness in mags.	<i>p</i> Diurnal parallax
μ Eccentric anomaly ¹ (or E).	<i>a</i> Semi-major axis of ellipse	<i>k</i> Gaussian gravitation constant	<i>q</i> Perihelion distance
μ Micron, = 1/1000th mm.	<i>b</i> Semi-minor do	<i>l</i> Heliocentric longitude	<i>r</i> Radius vector, in A.U.s
$\mu\mu$ 1/millionth mm.	<i>b</i> Heliocentric latitude	M Mean anomaly ³	T Time of perihelion passage
π Annual parallax	<i>c</i> Colour index	...	<i>v</i> True anomaly ⁴
ρ Radial velocity, + receding	D Diameter	...	<i>z</i> Zenith distance

¹ An artificial angle from perihelion, given by Kepler's equation, $M = \mu - e \sin \mu$. ² Ratio which the distance between the centre and the focus of an ellipse bears to the semi-major axis. ³ Calculated angle from perihelion, assuming uniform motion. ⁴ Actual angle from perihelion.

* ϖ is another form of π .

A STAR ATLAS

AND REFERENCE HANDBOOK

I.—NOTES ON STAR NOMENCLATURE, &c.

The Constellations.—The origin of most of the constellation names is lost in antiquity. COMA BERENICES was added to the old list (though not definitely fixed till the time of Tycho Brahé), about 200 B.C.; but no further addition was made till the seventeenth century, when Bayer, Hevelius, and other astronomers, formed many constellations in the hitherto uncharted regions of the southern heavens, and marked off portions of some of the large or ill-defined ancient constellations into new constellations. Many of these latter, however, were never generally recognised, and are now either obsolete or have had their rather clumsy names abbreviated into more convenient forms. Since the middle of the 18th century, when La Caille added thirteen names in the southern hemisphere, and sub-divided the unwieldy Argo into Carina, Malus (now Pyxis), Puppis, and Vela, no new constellations have been recognised. Originally, constellations had no boundaries, the position of a star in the 'head,' 'foot,' &c., of the figure answering the needs of the time; the first boundaries were drawn by Bode in 1801. For List of Constellations, see last page.

Star Nomenclature.—The star names given on the last but one page have, for the most part, been handed down from classical or early mediæval times, but only a few of them are now in use, a system devised by Bayer in 1603 having been found more convenient, viz., the designation of the bright stars of each constellation by the small letters of the Greek alphabet, α , β , γ , &c., the brightest star being usually made α , the second brightest β —though sometimes, as in Ursa Major, sequence, or position in the constellation figure, was preferred. When the Greek letters were exhausted, the small Roman letters, a, b, c, &c., were employed, and after these the capitals, A, B, &c.—mostly in the Southern constellations. The capitals after Q were not required, so Argelander utilised R, S, T, &c., to denote *variable* stars in each constellation, a convenient index to their peculiarity (see also p. 40).

The fainter stars are most conveniently designated by their numbers in some star catalogue. By universal consent, the numbers of Flamsteed's British Catalogue (published 1725) are adopted for stars to which no Greek letter has been assigned, while for stars not appearing in that catalogue, the numbers of some other catalogue are utilised. For convenience of reference, the more important star catalogues are designated by recognised contractions: thus, "B.A.C. 2130" is at once known by astronomers to denote the star numbered 2130 in the British Association Star Catalogue, published in 1845. A list of some of the best-known catalogues, and their contractions, is given p. vii. In most star catalogues a number is assigned to each star included in them, whether it has a Greek or other letter, or not. Thus, *Vega* is α LYRÆ, 3 LYRÆ (Flamsteed's number), and Groombridge 2616, the latter catalogue being arranged in order of Right Ascension, no notice being taken of the constellations.

The usual method of denoting any lettered or numbered star in a constellation is to give the letter, or number, followed by the genitive case of the Latin name of the constellation. Thus α of CANES VENATICI is described as α CANUM VENATICORUM. A list of these genitives is given in the list of constellations on the last page, facing the cover.

But boundaries being indefinite, catalogues and charts prepared before 1930 may differ as to which of two adjacent constellations a star belongs. Flamsteed, for instance, numbered in Camelopardalis several stars now standardised in Auriga. Similarly, a star might be numbered by error in two constellations, as sometimes happened with Flamsteed's stars, or Bayer might assign to the same star a Greek letter in two constellations, as ancient astronomers had defined it as belonging to both constellation figures. Thus β Tauri = γ Aurigæ, and α Andromedæ = δ Pegasi.

Flamsteed arranged his stars by constellation and number, 1, 2, 3, &c., in order of 'Right Ascension,' i.e., by the number of hours and minutes they southed after the southing of a certain zero point among the stars. This is convenient for reference, as the stars follow a regular sequence, but they may become displaced from that order in course of time owing to 'precession' (the slow annual movement among the stars of the zero point from which Right Ascension is measured), if they have nearly the same Right Ascension, but considerably different Declination.

Constellation Boundaries.—Those first drawn by Bode were by no means adhered to by later astronomers, and the lack of definite limits became so inconvenient that in 1930 the International Astronomical Union standardised them along arcs of circles on the celestial sphere—those of Right Ascension and Declination on Jan. 1, 1875—just as treaties sometimes define boundaries of countries by lines of latitude and longitude. That date was adopted as saving unnecessary work, Gould having already charted most of the Southern constellations on that basis.

The new boundaries—drawn to agree as nearly as possible with those of the best star atlases—never change their positions among the stars, though as a result of precession they no longer exactly follow arcs of Right Ascension and Declination, and will not again do so for 25,800 years—the precessional period. The boundary-epoch, however, being defined, a new object is readily assigned to its proper constellation.

II. NOTES ON ASTRONOMICAL TERMS.

The Star Sphere is an expression used for convenience in speaking of the heavenly bodies and their positions with respect to one another. The name is derived from the appearance presented by the heavens as seen from the earth, the earth being apparently at the centre of a vast hollow sphere, which makes a complete revolution every day, and to the inside surface of which the stars seem fixed—for they do not sensibly change their place relatively to one another, in spite of their daily revolution, and hence are called ‘fixed’ stars. Of course, only half of the star sphere can be seen, at the same moment, from any place on the earth—or slightly more, as refraction gives $\frac{1}{2}^\circ$ additional.

The pivots, as it were, of this sphere—the *Celestial Poles*—are directly overhead at the terrestrial poles; and its equator—the *Celestial Equator*, or *Equinoctial*, half-way between the poles—is directly overhead at the terrestrial equator. It is therefore easy to indicate the positions of the stars by saying they are so many degrees north or south of the celestial equator (called the stars’ ‘Declination’), and so many degrees east of some meridian. The latter distance, however, is for convenience usually expressed in hours and minutes of *time* instead of degrees, as explained below, and is termed ‘Right Ascension’; but degrees of R.A. are used by observers of meteors, and for some other purposes.

Right Ascension.—The Right Ascension of a star (contracted “R.A.”) corresponds to the longitude of a place on the earth’s surface. The starting point is known as “The First Point of Aries,” a point in the sky situated on the celestial equator, nearly as far *below* γ PEGASI as α ANDROMEDÆ is *above* it—stars forming one side of what is known as “The Great Square of Pegasus”—or a little below the small star ω of PISCES: this point marks 0h. of R.A.

As the heavens circle completely round the earth once each day, it is easy to note how many hours, minutes, and seconds elapse between the time at which this point ‘culminates’ (*i.e.* attains its highest altitude above the horizon, see p. 5) and the time of culmination of any desired star. This interval is called the star’s Right Ascension. Thus every star which culminates at the same instant as the “First Point of Aries,” is said to have a Right Ascension of 0 hours, 0 minutes; all that culminate three hours later are said to have a Right Ascension of three hours, and similarly for any other interval, up to twenty-four hours, which is the same as 0 hours, 0 minutes. Strictly speaking, these hours, minutes, and seconds of Right Ascension are respectively very slightly shorter than the hours, minutes, and seconds of ordinary clocks, because the stars make a complete circuit of the earth in 23 hours, 56 minutes, 4 seconds, or in about four minutes less than a mean solar day. Observatories are provided with special clocks, regulated to keep this sidereal time, for reading off the exact instant of culmination, of planets, comets, &c., and thus finding their R. A.

In more scientific language, the First Point of Aries is the point in the sky at which the centre of the Sun crosses the celestial equator at the vernal equinox in March, but yearly it changes its position slightly among the stars, moving back westwards on the Ecliptic $50\frac{1}{4}''$ per annum (= about 3 seconds of R.A.), or a space equal to the apparent diameter of the Moon in about thirty-nine years. Though it retains its old name, it is no longer in the constellation of ARIES but in that of PISCES. This is why star charts get out of date: the starting point of measurement is not fixed, and both the Declination and Right Ascension lines in the chart after a while no longer represent the actual positions with reasonable accuracy, especially near the Celestial Poles. This backward motion is ‘precession.’

Declination.—The Declination of a star (contracted “Dec.”) corresponds to terrestrial latitude, and is measured by the number of degrees the star is north or south of the Celestial Equator, which is simply an extension as it were, of the terrestrial equator as far as the star sphere. As already mentioned, at the terrestrial equator the celestial equator is directly overhead; and similarly at any latitude on the earth’s surface, the stars with the same amount of Declination as the latitude will be directly overhead when culminating. The signs + and – are sometimes used instead of N. and S., to distinguish between North (+) and South Declination (–).

Stars with a *greater* declination than the co-latitude* of the observer (his latitude subtracted from 90°) never set, if both observer and star are on the same side of the equator, or never rise if they are on opposite sides of the equator. Thus in latitude 50° north, all stars with declination over 40° N. never set, or over 40° S. never rise.

North Polar Distance (contracted 'N.P.D.'), measured from the North Celestial Pole, is sometimes used instead of Declination, as mistakes are apt to arise with "N." and "S". It ranges from 0° at the N. Pole to 180° at the S. Pole.

Colures.—The colures will be found marked on celestial globes, &c. The *Equinoctial Colure* is the great circle passing through the Celestial poles and the First Point of Aries (also called the "equinox" or equinoctial point), and is the same as the circle of 0 hrs. and 12 hrs. of Right Ascension. The *Solstitial Colure* is the great circle of R.A. 6 hrs. and 18 hrs.

Hour and Declination Circles.—An *Hour Circle*, or a *Declination Circle*, is the great circle passing through a celestial object and the Celestial poles; the former term is perhaps preferable to the latter, which is liable to be confused with "Declination Parallels," which are not great circles. These terms are also applied to the graduated circles on equatorial mountings, the first being graduated in hours and minutes of R.A., the second in degrees of Declination.

The Ecliptic, shown on star charts, is another important great circle on the star sphere, which intersects the Celestial Equator at the first Point of Aries and the Autumnal Equinox. It indicates the path traced out by the centre of the Sun as it travels among the stars in its (apparent) annual circuit of the heavens. That is to say, if we could see the Sun and the stars behind it at the same moment, day by day we should find the Sun exactly following the line shown on the charts.

It also represents the *average path of each of the planets*, as seen from the Earth, the planets swinging backwards and forwards on each side of the Ecliptic, to an angular distance approximately equalling the inclination of their orbits to the plane of the Ecliptic. At maximum, the Moon and Mercury are 7° away from the Ecliptic, on either side; Venus, about 3½°; Saturn, 2½°; Mars, Jupiter, and Neptune, less than 2°; and Uranus about ¾°.

The Poles of the Ecliptic are situated at 90° of celestial latitude, and may be regarded as fixed points on the star sphere. The position of the Northern Pole of the Ecliptic (R.A. 18h. 0m., Dec. 66° 33' N.) is very nearly marked by the nebula H.IV.37 in Map I.: the Southern Ecliptic Pole is R.A. 6h. 0m., Dec. 66° 33' S, between ϵ and η^1 Doradus. *The Plane of the Ecliptic*, in which the Ecliptic is situated, passes through the centres of the Earth and of the Sun.

The Obliquity of the Ecliptic is the inclination of the Earth's Equator to the Ecliptic, or the angle which the plane of the Ecliptic makes with the plane of the Equinoctial or Celestial Equator; mean obliquity, Jan. 1, 1925, 23° 26' 56", decreasing 0".47 annually. The apparent or true obliquity may differ from the mean as much as 9", owing to nutation.

Invariable Plane of the Solar System.—A plane that passes through the centre of gravity of the Solar System, and does not change its position in space as the result of mutual planetary perturbations—as the Ecliptic plane does very slowly—and can thus be used as an unvarying reference plane. It is inclined 1° 35' to the plane of the Ecliptic, the longitude of its ascending node being 106° 35'.

The Zodiac is the belt of the sky extending 8° on either side of the Ecliptic, within which the Moon and principal planets are always to be found.* It is divided into twelve 'Signs,' each 30° in length, but, owing to precession, the signs of the Zodiac do not now coincide with the *constellations* of the same name. For symbols of the Signs, see p.viii.

Other Methods of Recording the Positions of Celestial Objects.—While Right Ascension and Declination, referring objects to the plane of the Celestial Equator, afford the most convenient means for finding or recording the positions of objects on the star sphere, for many astronomical purposes the Celestial Equator is not a convenient circle of reference, and various other great circles are substituted for it. The principal reference planes and great circles used by astronomers are given below; the amateur observer will come across most of them when consulting the *N.A. Tables*.

The position of an object is indicated as follows, with respect to the:—

1. Celestial Equator	... ..	by its Right Ascension and Declination	... ..	(p. 2)
2. Ecliptic, (a) from the Earth's centre	..	Geocentric Longitude and Latitude	... ..	(p. 4)
3. " (b) " Sun's " ..	..	Heliocentric " " ..	... ..	(p. 4)
4. Milky Way, or Galactic Plane	... ..	Galactic " " ..	... ..	"
5. Sun's Equator	... ..	Heliographic " " ..	... ..	"
6. Moon's Equator	... ..	† Selenographic " " ..	... ..	"
7. Horizon of the Observer	... ..	Altitude and Azimuth	... ..	"
8. Meridian " " ..	..	Hour Angle ... ..	... ..	(p. 5)
9. Hour Circle, or Declination Circle	... ..	Position Angle	... ..	"
10. Limb of the Sun, Moon, or Planet	... ..	Distance from the Vertex, or from the North Point	..	"

It will be seen from the above that there are several kinds of Latitude and Longitude used in astronomy. But unless qualified by an appropriate adjective, "Latitude" and "Longitude," when used by themselves, are in astronomy always understood to mean Geocentric Latitude and Longitude, referring objects to the Ecliptic and the Earth's centre. The others are explained under their own headings.

* Pluto excepted, which was unknown when the Zodiac was formed.

† Similarly for the planets, the term for Jupiter being *zenographic*, and for Mars *areographic*.

Longitude and Latitude (unqualified by an adjective) refer celestial objects to the Ecliptic instead of to the Celestial Equator, and therefore do not correspond to terrestrial longitude and latitude. They are required for calculations involving the angular distance from the Sun of planets, comets, &c., as seen from the Earth, such as the lunar and planetary phases, conjunctions, oppositions, &c.

The *Longitude* of a celestial object is the angle in degrees (0° to 360°) measured eastwards, between the First Point of Aries (γ) and the foot of a perpendicular drawn from the object to the Ecliptic. Similarly, the *Latitude* of a celestial object is its distance in degrees North or South of the Ecliptic, measured on an arc at right angles to the Ecliptic. As ordinarily used, 'latitude' and 'longitude' are always understood to refer to *geocentric* latitude and longitude, *i.e.*, as observed from the Earth's centre, as contrasted with the heliocentric longitude (see below).

Longitude and Right Ascension both start from the First Point of Aries, and are both measured eastwards, but the former is measured in degrees along the *Ecliptic*; the latter along the *Celestial Equator*, in hours, &c.—1 hour being exactly 15° , and 4 minutes exactly 1° . As the plane of the Ecliptic lies at an angle to the Celestial Equator, a movement of 1° in longitude does not exactly correspond to 1° (*i.e.* $\frac{1}{15}$ hour, or 4 minutes) in Right Ascension, because (*a*), the direction of measurement is different, and (*b*), the respective degrees may differ in length on the star sphere—as, for instance, where the 'great circle' degrees of the Ecliptic traverse the narrower R.A. degrees measured on the parallel of Dec. 20° .

Similarly, Latitude must not be confused with Declination. Both are measured on arcs of great circles, but whereas all circles of Declination pass through the Celestial Poles, all circles of latitude pass through the Poles of the Ecliptic, which are in quite a different position on the star sphere from the Celestial Poles. The circles of Latitude are, therefore, always inclined to those of Declination, hence a motion of 1° in latitude is never a motion of 1° in declination.

Heliocentric longitude and latitude, used for planets or comets, are measured as from the Sun's centre, instead of the Earth's. The first is measured eastwards in degrees (0° to 360°) along the Ecliptic from the First Point of Aries, the second in degrees N. or S. of the Ecliptic. The Earth's heliocentric longitude is always the same as the geocentric longitude of the Sun + 180° . Heliocentric longitude is convenient in planetary and cometary orbital calculations, as it is independent of the Earth's orbital motion, &c.

Heliographic* and **Selenographic**, latitude and longitude refer objects to the planes of the solar and lunar equators, respectively—the equator with reference to the axis of rotation. They thus exactly correspond to terrestrial latitude and longitude, and positions are measured by means of them in the same way—by latitude N. or S. of the solar and lunar equators in degrees, and by longitude along the Equator from a central meridian. Their chief use is for recording the positions of markings on the surface of the Sun or Moon, such as sunspots, lunar craters, &c.

The zero meridian on the Moon is that of the 'mean centre' of the disc, and longitude is measured E. or W. of it in degrees. In the case of the Sun, on which there are no permanent markings, the meridian is to some extent an arbitrary one, based on an assumed unvarying sidereal rotation period of 25.38 days; the longitude is reckoned from 0° to 360° , measured from left to right across the apparent disc (non-inverted), *i.e.*, in the direction of the Sun's rotation.

Extended to the star sphere, Heliographic and Selenographic latitude and longitude correspond to solar and lunar Declination and R.A., and are convenient for finding the position of the Sun's equator with reference to the centre of the disc, and the amount of lunar libration. These are published annually in the *Nautical Almanac*.

Zenographic and Areographic latitude and longitude refer objects to the equator and prime meridian of Jupiter and Mars respectively. *Zenocentric*, *Areocentric*, *Saturnicentric*, relating to the centre of Jupiter, &c., are also used.

Galactic latitude and longitude refer objects to the mean plane of the Galaxy or Milky Way, which is important in connection with problems regarding the distribution of the stars on the star sphere. Galactic latitude is measured in degrees N. or S. of the Galactic Plane†; Galactic longitude, along the Galactic Plane in degrees 0° to 360° , starting from its intersection with the Celestial equator about R.A. 18h. 40m. to 18h. 50m., and measured to the left from 0° .

Altitude, Azimuth, Meridian, &c.—These refer the positions of celestial objects to the observer's horizon. The *altitude* of a heavenly body is its vertical angular distance in degrees above the horizon; its *azimuth*, the horizontal angular distance in degrees between the observer's south or north point, and the foot of a perpendicular drawn from the object to the horizon. In the Northern Hemisphere, azimuth is usually measured from south (0°) westwards, *i.e.*, from the *meridian*, which is the great circle passing through the Celestial poles and the north and south points of the observer. The *zenith* and *nadir* are the points in the sky directly over the observer's head and below his feet, respectively, *i.e.*, the poles of the horizon; the *prime vertical* is the great circle passing through the zenith and the observer's east and west points, corresponding to the Colures in R.A. and Declination; the *amplitude*, the arc of the horizon between the exact east or west point, and the foot of the vertical circle passing through the object.

* Or Heliographical.

† For fuller notes see page 28, and third last page of Atlas.

Culmination, Transit, &c.—A star 'culminates' when it reaches its highest point above the observer's horizon. In the Northern hemisphere this invariably takes place when the star is due south of the Pole; in the Southern, when it is due north. 'Meridian passage,' 'on the meridian,' 'returns to the meridian,' 'transit,' 'upper transit,' and (in northern latitudes, when S. of the zenith) 'southing,' have the same meaning as culmination. But applied to Jupiter's 'zero meridian' (p. 26), 'transit' means the instant at which that zero meridian is seen to cross the centre of his disc.

Transit is also used in another sense, to express the crossing of *Mercury* or *Venus* as black circular spots in front of the Sun's bright disc; or of a satellite, or its shadow (see p. 26), across the disc of its primary planet. The *ingress* is the entrance on the disc, and the *egress* the departure from the disc.

Lower culmination or *lower transit* of a 'circumpolar' star, which never sets, occurs when the star is *nearest* the horizon, 12 sidereal hours after the upper transit, and at the opposite side of the celestial pole. *Moon-culminating stars*, were used by sailors—those that culminate about the same time as the Moon, and do not differ much in Declination.

Hour Angle.—The hour angle of a celestial object refers it to the meridian of the observer; it is used in calculating the altitude or azimuth of an object, the time of its rising or setting, &c., and may be defined as the difference between its Right Ascension and the hour of R.A. on the meridian at the time of an observation, or the angle which the hour-circle passing through the object makes with the meridian, usually expressed in hrs., &c., of sidereal time.

Position Angle: North Point.—The Position angle may be described as the angle which the line joining a pair of double stars, or the axis of the Sun or of a planet, makes with a line drawn perpendicular to the observer's horizon through the object, at the instant of its culmination. This line is in the plane of the observer's meridian, and, therefore, of the hour-circle passing through the object: the hour circle thus forms a convenient basis of reference for inclination on the star sphere at any time. More accurately it is defined as follows:—

(a). The position angle of a double star is the angle which the line joining the components makes with the hour-circle passing through the brighter star of the pair. This angle is measured from the *North Point* (or point on the hour-circle nearest the North Celestial Pole, in the field of view) from 0° to 360°, going round by E., S., and W. (See p. 33).

(b). The position angle of the Sun's or of a planet's axis is the angle which it makes with the hour-circle passing through the Sun's or planet's centre. This varies throughout the year, and is given in the *Nautical Almanac*. In the case of the Sun, however, on the same date it is approximately the same year after year.

The angle is measured from the hour-circle to the N. pole in degrees: in the case of the Sun, E. or W. of the hour-circle (+ being E. and - W.), but for the Moon and planets, from 0° to 360°, as for double stars (see diagram p. 33).

Vertex, Limb.—This system is used in connection with occultations of stars by the Moon or a planet (p. 32), and refers the points of disappearance of the star behind the edge of the Moon's disc, and of its re-appearance, to a line perpendicular to the horizon (of Greenwich for the *Nautical Almanac* figures). The *limb* is the edge of the disc of the Sun, Moon, or of a planet; the *vertex*, the point on its limb furthest above the observer's horizon. Distances from the vertex are counted eastwards from 0° to 360°. The *cusps* are the horns of the crescent Moon, Venus, or Mercury.

Motions of Planets or Comets.—A planet or comet is in *perihelion* (π) when at its nearest distance (real, not apparent) to the Sun, and in *aphelion* when it has reached its greatest distance from it: it has *direct* motion, when its orbital motion, with respect to the Sun, is from west to east; *retrograde* motion, if from east to west. Similarly satellites, with respect to their primaries. *Perigee* is the point of the Moon's orbit which is nearest the Earth, and *apogee* that which is most distant from it; but the terms are sometimes applied to the planets in the same sense. *Recession* means that a comet is moving away from the Sun, after perihelion.

Planets are said to be *stationary*, when their seeming movement east or west among the stars is changing to the reverse direction, and *retrograde* when their seeming motion among the stars is westerly for a time instead of easterly, or *direct*. The *elongation* of a planet is its angular distance (*i.e.* its distance in degrees) from the Sun as seen from the Earth; the *greatest elongation* of Mercury or Venus being at the time when this angular distance is at its maximum.

When a planet or comet, in its movement among the stars, reaches the Ecliptic on the star sphere—that is, in reality, reaches the *plane* of the Ecliptic—it is said to be at a *node* of its orbit. If it is passing from the north to the south side of the Ecliptic, it is at the *descending node* (symbol $\Im$); if the reverse, at the *ascending node* (symbol $\Im^2$). The nodes, in fact, are the points of intersection of the planet's orbit with the Ecliptic.

Conjunction.—Planets, &c., are in *conjunction* (symbol $\odot$) with the Sun, Moon, or another planet, when their longitudes are the same—Mercury or Venus (known as the *inferior planets*) being in *inferior conjunction* with the Sun when the conjunction occurs while they are on the near side of the Sun; or in *superior conjunction* if they are on the far side of the Sun from the Earth (*i.e.*, the Sun being between the planet and the Earth); 'conjunction' more rarely denotes similarity in R.A. The Moon is in *syzygy* when in conjunction or opposition, *i.e.*, when New or Full.

Opposition.—Mars, and the planets beyond (the *Superior Planets*), are in *Opposition* (symbol $\oslash$), when 180° of longitude (or 12 hrs. R.A.) away from the Sun on the star sphere; they are then on the meridian about midnight, and also nearest the Earth. An opposition is 'favourable' if the Earth and the planet are then near the point at which their orbits most closely approach, and as this point is always about the same longitude, favourable oppositions *always take place about the same date in the year*, and the favourableness or otherwise of any opposition can always be judged by its nearness to, or remoteness from, that date; those six months later are the least favourable (see pp. 24 to 26).

Apsides.—The apses (plural of apsis) of a planet or satellite are the two points in its orbit where it is nearest to and furthest away from its primary. The *line of apses*, joining each apsis, is the major axis of the orbit.

Phase denotes (a) the extent to which the Moon or a planet is illumined by the Sun, as seen from the Earth; this depends on their angular distance from him; (b) appearance or configuration, as in the *N.A.* 'Phases of the eclipses of Jupiter's satellites'; *aspect* is also sometimes used in this sense; (c) the stage of progress towards maximum or minimum of a variable star, + denoting the number of days towards the former, - towards the latter.

Phase effect is greatest when the Superior planets are in *Quadrature* ($\square$), i.e., 90° of longitude (or 6 hrs. R.A.) from the Sun, and therefore on the meridian about 6 a.m. or 6 p.m.; it is only observable in the case of Mars, which becomes gibbous, and on Jupiter, where a slight shade appears along the limb furthest from the Sun.

Appulse.—An Appulse is the near approach of one celestial body to another; the term may also be used for culmination, or coming into conjunction; as, the appulse of a star to the meridian, of the Moon to the Earth's shadow, &c.

Albedo.—The albedo of a planet is its light-reflectivity per unit of actual, not angular, area; the Table indicates the amount, according to several investigators, of the light from the Sun which they respectively reflect.

	Mercury	Venus	Earth	Moon	Mars	Jupiter	Saturn	Uranus	Neptune	Clouds
Zöllner (1865),	.13	.50	...	.17	.27	.62	.52	.64	.46	(.65-.72)
Müller (1897),	.14	.76	.20	.13	.12	.62	.72	.60	.52	Snow
Russell (1916),	.07	.59	.45	.07	.15	.56	.63	.63	.73	(.70-.78)

Primary:Satellite.—Two celestial bodies which revolve round a common centre of gravity are 'physically connected,' and the larger is called the *primary*, the smaller the *satellite*. In the case of a star, 'companion' is often used for the latter, but the term does not necessarily imply physical connection, merely close visual proximity.

Planetary Periods.—The *Sidereal Period* of a planet, its true period of revolution round the Sun, is the time it takes to make a complete circuit round the star sphere, from star to star again, as seen from the Sun, not the Earth.

The *Anomalistic Period* is the interval from any point in a planet's orbit to the same point again—for instance between successive returns to perihelion or to aphelion; this period, and also that of successive returns to the same node, is practically the same as the planet's sidereal period.

The *Synodic or Apparent Period* of a planet is the interval, as seen from the Earth's centre, between successive oppositions (or conjunctions) with the Sun; the synodic periods of the satellites of Jupiter, &c., are the intervals between successive similar elongations (or similar conjunctions) with their primary, as seen from the Earth.

The Synodic period determines the dates of opposition, conjunction, &c.; the Sidereal period, those of the opening and closing of Saturn's rings, also of the recurrence of a planet's greatest N. or S. latitude—important for Mercury.

Rotation Periods.—The *Sidereal* rotation period of the Sun, or of a planet or satellite, its true period of axial rotation, is the interval between a star's successive returns to the same meridian on the Sun's or planet's surface.

The Sun and the planets* have the same 'direct' rotation as the Earth (from W. to E. looking south), but to us revolve from left to right, because the hemisphere we see faces in the opposite direction from our hemisphere.

The *Synodic or Apparent* rotation period of the Sun, or of a planet, is the interval, as seen from the Earth's centre, between successive returns of a meridian on its surface to the centre of the disc. The apparent rotation periods of the superior planets merely vary to and fro a very little on each side of the sidereal rotation periods.

Vernal Equinox, strictly speaking, denotes only (a) a time—the instant, once a year, when the Sun's centre crosses the Celestial equator from the S. to the N. hemisphere, on March 20-21; (b) a yearly position on the star sphere—that of the First Point of Aries at the same instant, a position which coincides with the Sun's centre: 'vernal' equinox is also sometimes used to denote the position of the First Point of Aries at any time when a correct sidereal clock shows 0 hrs., but as this Point changes continuously, 'vernal' should not be used in this sense. Similarly the *Autumnal Equinox* is the instant of the Sun's yearly crossing into the S. hemisphere, on Sept. 23-24; but in the S. hemisphere this is the date of the vernal equinox, the March date being the autumnal one. At the equinoxes, day and night are equal all over the Earth.

The Equinox (short for *Apparent or True Equinox*) of any date is the point of intersection, on the star sphere, at any moment, of the Celestial equator and the Ecliptic—i.e., it is the position of the First Point of Aries: when a correct sidereal clock shows 0 hrs. it is on the meridian. Each day, precession carries this point to a slightly different place on the star sphere from that of the day before, so that R.A. is measured from a new starting-point every day.

The *Mean Equinox* of any date is obtained by correcting the Apparent equinox for nutation, by which it is affected. The relation between the two is analogous to that which the position of the Mean Sun bears to that of the True Sun.

* Mars, Jupiter, Saturn.

The Day.—A 'day,' reckoned with respect to any celestial body, is the interval between its successive returns to the meridian: 'day' is also used in another sense, to denote the period of a planet's axial rotation. Three 'days' are used in astronomy: (1) The ordinary *solar day* of 24 hours—strictly speaking, the interval between successive transits of the real Sun across the meridian, (varies 48 secs.), but in practice taken as the unvarying interval between those of a supposed 'Mean Sun,' which gives the *average* solar day; a new day or date on the Earth begins on the *Date Line*—the meridian 180° E. of Greenwich, with deviations for geographical, &c., exigencies; (2) The so-called *Sidereal Day* of 24 sidereal or R.A. hours, the interval between successive transits of the Equinox across the meridian (23 h., 56 min. 4.0905 secs. mean time): it is really the *equinoctial* sidereal day, being measured from the ever-moving Equinox of each day; (3) The *True Sidereal Day*, the exact period of the Earth's axial rotation, as shown by successive transits of a star across the meridian (23 h. 56 m. 4.0996 secs. mean time); each year it falls behind (2) by 3.3 secs. mean time.

A *Lunar Day*, the interval between successive meridian transits of the Moon, varies from 24 h. 38 m. to 25 h. 6 m., and averages 24 hrs. 51 m.; it determines the tide-interval from high water to high water, which is *half* a lunar day.

Our *Mean Time* (Mean Solar Time) is based on the mean solar day; *True*, or *Apparent Solar Time*, or *sundial time*—which varies slightly from day to day—on the Sun's actual southings; *Sidereal Time*, on the sidereal day.

The Year.—The *Solar*, *Equinoctial*, or *Tropical Year* (365.2422 solar or 366.2422 sidereal dys) in which the seasons recur, is determined by successive returns of the Sun to the same equinox; or to the same 'tropic' or 'solstitial point,' the point on the star sphere where he attains his greatest distance N. or S. of the Celestial equator, on mid-summer or mid-winter days: 'tropic' also denotes the Declination circles on the star sphere which pass through the solstitial points.

The *Sidereal Year* (365.2564 days) is the interval between successive conjunctions of the Earth with a star, as seen from the Sun; it is the true period of the Earth's orbital revolution round the Sun.

The *Anomalistic Year* (365.2596 days) is the mean interval between the Earth's returns to perihelion about Jan. 2; as it varies a day or two on each side of the mean, perihelion may occur twice in a calendar year, or not at all.

The *Julian Year*, used in our calendar, has exactly $365\frac{1}{4}$ (365.25) days: the fraction is adjusted by having *Calendar Years* of 365 or 366 days, the latter in every fourth year divisible by 4 (leap yr.). All years have been Julian since the Julian year was instituted in 45 B.C., except (a) 1582, which by the Gregorian revision of that year had only 355 days (Britain and its American colonies substituted 1752, which had only 355 days instead of 366), and (b) 1700, 1800, 1900, restricted to 365 days by the new Gregorian rule omitting leap year in century years not divisible by 400.

The *Lunar Year* (354.3670 days) of twelve lunations, used in the Mahomedan calendar, has twelve months of 29 or 30 days each, based on the *phasis*, or first observation, of each New Moon; it may have 354 or 355 days.

Bessel's Fictitious Year, used in the *N.A.* Mean Star Places, begins at the instant when the Sun's apparent mean longitude is 280° , on Dec. 31st civil date (in the *N.A.* 'Jan. 0,' to which it corresponds), or on Jan. 1st.

The *Eclipse Year* (346.6200 days), the interval between successive returns of the Sun to the same node of the Moon's orbit, is the period of possible recurrence of both solar and lunar eclipses, which can only take place when these bodies are within a small distance from the node. 19 eclipse years are 6585.78 days, almost exactly the same as the ancient 'Saros' cycle of 6585.32 days, (18.03 yrs.), the period after which the same eclipses occur regularly for centuries.

Lunar Months.—The *Synodic Month*, or *Lunation* (29.5306 days), the period from New Moon to New Moon, or between similar phases, varies between $29\frac{1}{2}$ and $29\frac{3}{4}$ days. New Moons recur on the same day of the year* every 19 years—the ancient 'Metonic cycle.' The more accurate 'Calippic cycle' has 76 years (19×4) or 940 lunations.

The *Anomalistic Month*, 27.5546 days from perigee to perigee, on the average, is the period of the Moon's changes in luminosity and angular diameter; it varies in length a day or two on each side of the mean.

The *Nodical Month*, or *Draconitic Period* (27.2122 days), from one of the nodes to the same node again, is the period after which the Moon again attains her greatest distance N. or S. of the Ecliptic, during any month.

The *Sidereal Month* (27.3217 days), in which the Moon circuits the star sphere back to the same star, is the period after which the Moon's proximity will again hinder observation of a star. Her dates of conjunction with the planets are given in the *N.A.* under 'Phenomena.' The *Tropical Month*, from equinox to equinox, has 27.3216 days.

The Julian Period, useful for calculating the exact interval between dates at long intervals apart, starts on Jan. 1, 4713 B.C., at noon. The *Julian Day*, or *Julian Date* (contracted J.D.) is the number of days that have elapsed since the beginning of the Julian Period; a Table in the *N.A.* gives the Julian Day corresponding to Jan. 1 of each fourth year from 1 B.C., which the Table calls 'A.D. 0'. In ordinary chronology, A.D. 1 is the year following 1 B.C., and as there is no zero year, when B.C. and A.D. years are added, the resulting period is one year too great; or, if subtracted, one year too little. Calling 1 B.C., 'A.D. 0 (astronomical)'; 2 B.C., '1 B.C. (astron.),' and so on, gets over the difficulty.

For astronomical purposes, decimals of a day are employed with the Julian Day, instead of hours and minutes, as addition and subtraction are easier; thus Jan. 1, 1926, 9 p.m., astronomical time, is stated as J.D. 2,424,517.375, reckoned from noon. But the Julian Period being still reckoned from noon, not midnight, note that all astronomical hours less than 12 h. 0 m. (or .5 day), still belong to the Julian Day *preceding* the civil date. Thus Jan. 1, 1926, 9 a.m., astronomical time, is J.D. 2,424,516.875, i.e., Dec. 31, 1925, 21 hrs., of the Julian Period. (Decimals of a day, p. 36).

* Subject to leap year disturbances.

Occultation Period.—Owing to the westward motion of the Moon's node, along the Ecliptic (about $1\frac{1}{2}^\circ$ per nodical month), the Moon's monthly path among the stars is always changing; it completes the circuit of the star sphere in 18·59 years. *On the average*, therefore, every star within about $6\frac{1}{4}^\circ$ of the Ecliptic has the chance of being occulted twice during that interval, when it is passed successively by the ascending and descending quadrants of the path. These 'passings' are at average intervals of $9\frac{1}{4}$ years for stars on the Ecliptic itself; for other occultable stars the interval between the passings shortens as the distance from the Ecliptic increases (with a correspondingly longer interval to the next pair), till, at the occultable limit, the two passings coincide. But the intervals are not constant, owing to the varying inclination of the Moon's orbit, the node's irregular and sometimes reversed motion, &c. For the same reasons, during many months an occultation *may* be repeated, before the path finally departs from the star.

Sidereal Time, used for measuring R.A., is the interval, in sidereal hours, minutes, and seconds, since the preceding meridian passage, at a given place, of the True Equinox or First Point of Aries; each sidereal hour is $1/24$ th of that interval, and shorter than the mean solar hour by 9·83 secs. mean time, making the sidereal day 3m. 59·1s. shorter than the mean solar day. Each observatory regulates its sidereal clock to this time by the star Tables in the *N.A.*, so as to obtain at any moment the hour of R.A. on the meridian: whenever that clock shows 0 hrs, the True Equinox is on the meridian of that place. Sidereal time is thus a *local* sidereal time, different from that of every observatory not on the same meridian, and though, being measured by a clock, it is a uniform time, it is neither Mean sidereal time, which would be measured from the Mean equinox, nor actual sidereal time, which is very slightly irregular, precession not being absolutely uniform (*Equation of the equinoxes*); the error, however, is too small to give practical inconvenience.

Mean Time, shown by ordinary clocks, is the interval since the preceding 'mean midnight,' or instant when, during the night, an ordinary clock, correctly regulated to the average length of the mean solar day from noon to noon, shows 12 hrs., or a 24-hour clock shows 24 hrs. *Mean Noon* is the instant when mean time clocks indicate XII, at mid-day.

Apparent (Solar) Time, or *True Time*, is sundial or *Apparent Local Time*, based on the observed interval between two successive meridian transits of the Sun's centre at any particular place. As these intervals are unequal, to obtain the true local *mean* time, a correction known as the *Equation of Time* must be added to, or subtracted from, the apparent time; this is given for each day in almanacs, sometimes on the sundial. The Sun and clock agree, however, on or about April 15, June 14, Sept. 1, and Dec. 25; on other dates the clock is before or after the Sun from a few seconds up to $14\frac{1}{2}$ – $16\frac{1}{2}$ minutes, the maxima being—before Sun, about Feb. 12, $14\frac{1}{2}$ m.; after, Nov. 2, $16\frac{1}{2}$ m.

Astronomical and Civil Time.—Both begin and end at midnight.* The astronomical day starts with 0 hrs., followed by I., II., . . . hrs., and the civil day with XII a.m., then I., II., . . . a.m., and so on until noon, which is XII^h astronomical and XII noon, civil. Thereafter, to avoid the use of a.m. and p.m., astronomers call I p.m. XIII^h, II p.m. XIV^h, and so on to midnight, XXIV^h, which ends their day. XII p.m. midnight ends the civil day.

Greenwich Mean Time (G.M.T.) now denotes the mean time for the meridian of Greenwich, starting at midnight for both civil and astronomical time. Previous to Jan. 1, 1925, astronomically G.M.T. denoted the time measured from noon, not midnight, as the recognised astronomical day—used until then in the *N.A.* and *A.E.*—ran from noon to noon; its last twelve hours (12–24 hrs.) were thus in the following civil day, which was confusing, as these Almanacs dated them in the day before the current civil date. Noon to noon astronomical time, when required, is designated G.M.A.T. = Greenwich Mean Astronomical Time; J.A.D. denotes Julian Astronomical Day = J.D.

Interval between two Phenomena.—If one is before and the other after midnight, Dec. 31, 1924, to obtain the true interval 12 hours must be deducted from the apparent interval obtained from the dates and hours in the *Nautical Almanac* (or *A.E.*), to allow for the astronomical day having been shifted back 12 hours on Jan. 1, 1925, so as to coincide with the civil day.

Greenwich Civil Time (G.C.T.): Universal Time (U.T.) (Germany, Weltzeit—world-time) are usually employed outside Great Britain to denote the new G.M.T.; before 1925, G.C.T. meant the civil G.M.T. beginning midnight.

Standard Time is an international arrangement for facilitating inter-communication, whereby (a) Greenwich is taken as the universal zero of longitude and time, and (b) the official mean time of each country or large district differs from Greenwich time by an exact multiple of half an hour. For the various Standard Times see almanacs.

Local Mean Time, required for finding the clock time of sunrise, southing of the Sun, &c., is the true *mean* time of the meridian of a place. On the standard meridian, at a given hour, the local time is slower compared with that of places to the E., where the day begins sooner, but faster compared with that of places to the W.; hence to obtain local mean time, add to, or subtract from, the standard mean time, 4 minutes for each degree the place is E. or W., respectively, of the standard meridian. But when using, in other places, the Sunrise and Sunset Tables calculated for the local time of the standard meridian (see the *N.A.*), the longitude correction must be *subtracted* for E., *added* for W., as the phenomena take place earlier and later, respectively, than at the standard meridian.

Light-Time, the time taken by light to travel from a celestial body to the Earth at a given moment, has to be allowed for when computing true rotation periods, &c. For the Sun, at mean distance it is 498·58 secs. (8·31 min.); the maximum is about 8·4m., the minimum, 8·2m. The observed maxima and minima times of variable stars require a + or – light-time correction for the Earth's position, as periods are stated for the Earth at mean distance.

Apparent.—This word has constantly to be employed in astronomy because in literal fact ‘things are not what they seem.’ The movements we see, and the positions read off, are, for various causes, not necessarily the real movements or positions; thus, ‘apparent’ is used in the sense of ‘as viewed from the Earth’—apparent diameter, motion, displacement, &c.—or, as in almanacs, to distinguish ‘observed’ readings on the instruments from the ‘true’ values, ‘reduced’ from the former by eliminating the effects of refraction, aberration, &c. Thus there is apparent R.A., Noon, Time, &c.

Refraction.—All observations of position have to be corrected for atmospheric refraction, which raises a celestial object higher in the sky than its true position, by fully $\frac{1}{2}^{\circ}$ at the horizon, decreasing to 0° at the zenith.

Aberration.—The velocity of light is not infinite compared with the Earth’s orbital velocity, and the two velocities combined results in a small variable displacement (max. $20''.47$ on each side) of celestial objects from their true positions; the Earth’s rotation causes a lesser aberration. At the end of a sidereal year, however, a fixed star returns to its original place, so far as aberration is concerned.

Precession, observationally, is the difference in a star’s R.A. and Declination after one tropical year, as the result of that continuous change in the position of the Equinox on the Ecliptic known as the ‘Precession of the Equinoxes.’ This difference in R.A. and Dec. represents the co-ordinates of the annual linear precessional motion of each star in longitude. The precession of stars very near the Celestial Poles is very great—but quite misleading so far as actual motion is concerned; among the closely-crowded nearly-convergent circles of R.A. near the Poles, a movement of a few seconds in great-circle measure necessarily becomes many seconds in the very-small-circle measure of polar R.A.

In star catalogues, the annual precession is given in seconds of time for R.A., and in seconds of arc for Declination, + and – being directional; thus in correcting the star position, *add like signs, subtract unlike signs.*

Precession is a gyroscopic effect, caused by the Sun, Moon, and, to a trifling extent by the planets, acting on the protuberant equatorial region of the swiftly-rotating Earth; this causes the Celestial Poles to circle slowly round the Ecliptic poles, at a distance of nearly $23\frac{1}{2}^{\circ}$, in a period of about 25,800 years, equivalent to $50''.26$ per annum, or 1° in 71.6 years. In consequence of the movement of the Celestial poles, the Celestial equator also incessantly changes its position on the star sphere, continuously altering the R.A. and Dec. of every star.

As the result of precession, each star* passes successively through every hour of R.A. from 0 h. to 24 h., once every 25,800 years; also its Declination swings backwards and forwards, changing 47° ($23\frac{1}{2}^{\circ} \times 2$) every 12,900 years.

Nutation.—The precessional path traced on the star sphere by the Celestial Pole is a wavy line varying slightly from a true circle. This irregularity is called Nutation, being, as it were, a ‘nodding’ of the Celestial poles to and fro from the Ecliptic Poles, and though minute—about $9''$ on each side of the mean, or $18''$ in $18\frac{1}{2}$ years—perceptibly modifies the precessional displacement in R.A. and Declination. The Earth’s axis passes the mean position about 2800 times in the 25,800-year period. Nutation is due to the Moon’s being sometimes above and sometimes below the Ecliptic, and so not always pulling on the Earth’s equatorial protuberance in the same direction as the Sun.

Secular Acceleration.—A shortening of period, only detectable in ‘secular’ periods, i.e., those of the order of a century; (a) *Of the Sun*, the apparent shortening of the Earth’s tropical year by about 1.95 seconds per century, supposed to be really due to the lengthening of the Earth’s daily rotation period by tidal friction; (b) *Of the Moon*, a continuous decrease in the length of the lunar month, amounting to about $10''$ per century.

Osculating Orbit.—The orbit which a planet or comet would pursue if, at some specified instant, all the planets should cease to attract the body and leave it free to move under the attraction of the Sun alone.

Epoch.—The date for which an astronomical catalogue, chart, or position, &c., has been calculated, as, sooner or later, precession, proper motion, &c., perceptibly change the positions given, and comparison at future epochs would be of little use without this date. The usual date is Jan. 1st of the year; that of this Atlas is Jan. 1, 1920.

Ephemeris (plural Ephemerides). Any Table of calculated positions, &c., in connection with a celestial object. The *American Ephemeris* corresponds to the British *Nautical Almanac*, and has some Tables not given in the latter.

Equation.—A small correction on the figures actually observed, to eliminate instrumental, ocular, and other imperfections, grouped together as *Systematic Errors*—i.e., errors that always recur when the observations are repeated under the same conditions, and with the same instruments (*Accidental Errors* are those that do not recur, as from abnormal refraction, &c.). Also a similar correction for orbital irregularity, as in the *Equation of Time* and of the *Equinoxes* (p. 8). For the errors of the eye in observing, see an interesting paper in the *J.B.A.A.*, vol. 39, p. 4.

The Personal Equation of the observer affects observations of every kind, and for refined work has to be found by experiment; the transit records of one observer are regularly late or early compared with those of another observer.

Colour and Magnitude Equation, see p. 13. Transits of the same star recorded in the hours after sunset and before sunrise, respectively, also seem to require an equation, a difference of some 0.06 second having been noted.

Fundamental or Clock Stars, are stars the positions, &c., of which have been measured with the utmost care, and which are used as reference points for finding the R.A. of other stars with less labour. The positions of these stars for each day is given in the *N.A.*; they are called ‘clock stars’ because they are used for regulating the clocks.

Dependencies: a short, fairly accurate method of measuring positions on star photographs from the *Dependence Centre*—an imaginary point, close to the image of an asteroid or planet, the position of which can be exactly calculated.

Parallax is the angular difference in direction of an object when viewed from two different standpoints, expressed by the number of seconds or minutes of arc subtended by the line joining the two standpoints, *as seen from the object*. The parallax of a star is reckoned on a different basis from that of the Sun or of a planet.

In *Diurnal Parallax*, used for members of the Solar System only, the two standpoints are the Earth's centre and the observer, separated by the radius of the Earth's diurnal or *daily* circuit; when greatest it is termed the *Horizontal Parallax*, since the object is then on the observer's horizon; and decreases to zero at the zenith, when object, observer, and Earth's centre are in the same line; as ordinarily stated, it is the *Equatorial* horizontal parallax, for the Equator, where the Earth's radius is greatest. *Parallax in Altitude* is when the object is not on the horizon. The Moon has the greatest diurnal parallax, 57'; the next greatest is that of the minor planet Eros, 52'', at a near approach.

Annual Parallax—used for stars and nebulae only, their diurnal parallax being unmeasurably small—is the angle subtended by the mean radius of the Earth's orbit, or *yearly* circuit, as seen from a star. If this is known, the star's distance can be easily calculated, but the difficulty of observing the very minute angles involved makes the results somewhat uncertain except in the case of the very nearest stars; photographs taken six months apart have replaced, with far greater convenience, direct angular measurement, angles with a probable error as small as 0''.01 (1/360,000 degree) being measurable. The greatest parallax known (0''.765) is that of *Proxima Centauri*, a very faint star physically connected with α Centauri, but 2° away, that of α Centauri is 0''.758. *Proxima* is thus the nearest star.

A *Negative Parallax* (annual) is one prefixed by the *minus* sign—i.e., apparently less than the average parallax of the comparison stars: it may indicate that the errors of observation exceed the amount of the parallax, or that the comparison stars have been more displaced, or perhaps that some disturbing dark companion has to be reckoned with.

Stellar Parallax.—When stating a parallax it is usual to give the basis of measurement, so that the 'weight,' or degree of reliability, may be estimated, some of the many methods now available giving better results than others.

Trigonometrical Parallax, the foundation for the others, is that measured by angular observations, direct or photographic. When measured with reference to some other stars, assumed to be much more remote on account of their faintness and small proper motion, the parallax is called the *Relative Parallax*; if the average parallax of these reference stars can be estimated by some means, the relative parallax so corrected is called the *Absolute Parallax*.

Absolute Magnitude Parallaxes are calculated from the absolute magnitudes as deduced from the following phenomena; comparison with known trigonometrical parallaxes shows that each method gives results more or less in fair agreement:—*Cepheid* parallax, derived from the period of variation of 'Cepheid' variable stars (p. 29); it is probably very accurate: *Spectroscopic* parallax, from the intensity of certain lines in some types of spectra: *Spectral* parallax, from the spectral Type and Giant or Dwarf classification (p. 16). Parallax can also be calculated from surface brightness.

Dynamic or *Hypothetical* parallax is a probable parallax calculated from the period and angular dimensions of the orbit of a binary star, the mass of the system having to be guessed. As, however, the average star mass appears to be about that of the Sun (p. 16), this unknown factor can be estimated on that basis with little likelihood of introducing much error, as, fortunately, a very considerable change in the mass value makes only a small change in the parallax.

Secular parallax or 'parallactic motion' is deduced from the motion of the Sun per century, and the motion of a group of stars with respect to the Solar Antapex (p. 23); it will be of much importance in the future when the lapse of time enables proper motions to be measured with greater accuracy than is possible at present. *Secular Variation* of parallax is the change in the annual parallax caused by the radial motion of a star towards or away from the Sun, which after a long time must inevitably bring about a sensible alteration.

Group or *Statistical* parallax is based on the reasonable assumption that in a fair-sized group of stars, those of the same magnitude are at the same average distance, the visual magnitude being thus an index of their distance. It requires, however, a starting point based on some other parallax, such as *Secular* parallax.

Mass-luminosity parallax is found from the mass-luminosity relationship (p. 16).

Astronomical Unit.—The unit for measurements in the Solar System, and the base-line for stellar parallax, is the Earth's mean distance from the Sun, 92,897,400 miles, or 149,504,200 kilometres, the distance corresponding to the mean equatorial parallax 8''.80—the last four or five figures, of course, not being significant. This parallax was adopted internationally in 1896 as the basis for ephemerides, and is expected to be near enough to require no alteration when better measurements are available. The favourable 1931 opposition of *Eros* gave 8''.

Unit Distance. The angular diameter of a planet 'at unit distance,' used when comparing the diameters of planets, is that which the planet would have, as seen from the Sun's centre, if it were placed at a distance of 1 astronomical unit.

A million astronomical units has been called a *Siriameter*, a term first used by Sir W. Herschel in another sense.

Parsec: Light-year.—A *Parsec* is the distance of a star having a parallax of 1"; a *Light-Year*, the distance that light, travelling 186,300 miles (299,800 km.) per second, traverses in a year—a convenient popular unit.

10 parsecs (a *dekaparsec*, in Metric notation) is the distance at which absolute magnitude (p. 13) is computed; a *Kiloparsec* is 1000 parsecs. A *Megaparsec*, for remote nebulae, is a million parsecs, or $3\frac{1}{4}$ million light-years.

Distance-Unit	=Parsecs	=a Parallax of	=Astronomical Units	=Light-Years	=Billions of Miles		Billions of Kilometres	
					British (10 ¹²)	U.S. (10 ⁹)	British (10 ¹²)	U.S. (10 ⁹)
Light-year	0.3069	3" .259	63.290	1	5.88	5880	9.463	9463
Parsec ...	1	1" .000	206.265	3.259	19.16	19,160	30.840	30,840
Dekaparsec	10	0" .100	2,062.650	32.590	191.60	191,600	308.400	308,400

Radial Motion.—The Radial motion of a star is its apparent motion in the line of sight, either towards us or away from us: it is not the star's own real space motion (see below). The *Radial Velocity* is the radial motion expressed in miles or kilometres per second, which is found by the spectroscope to within $\frac{1}{4}$ mile per second under favourable circumstances: + is used to indicate recession from us, and - to indicate approach to us.

Proper Motion, or *Tangential Motion*, is a star's apparent angular motion (if any) on the star sphere at right angles to the line of sight, expressed in seconds of arc per year or per century; it is found by comparing the star's present position with that which it occupied at the time of the earliest reliable observation—precession, nutation, parallax, and aberration, being allowed for. As this angular motion is continuous, though in general very minute, it has to be taken into account when preparing a star catalogue for a given epoch (see note p. 39 as to + and -). The following are some of the greatest proper motions known: a long list is given *Astrophys. Journal*, vol. 41, 1914.

Ursa Major.	Groombridge 1830 (mag. 6),	Proper motion 7". annually	...	...	...	...	...
Pictor. ...	C.Z. 5 h. 243 (mag. 9),	" 9". "	...	...	...	...	...
Ophiuchus.	Munich 15,040 (Barnard's star, mag. 9.4)	10", found 1916, the greatest yet discovered	...	...	...	...	...

The observed proper motion is not a star's real tangential motion in space, but an 'apparent' motion, being affected by the Sun's own motion through space towards the Solar Apex (page 23). Some stars have practically no proper motion—a result due in general to their very great distance. The *Tangential Velocity* is the Tangential motion expressed in kilometres or miles per second: the star's distance must be known.

Linear Motion.—A star's linear motion is the resultant of (a) the radial motion, and (b) the proper motion, expressed in *lineal*, not angular, measure, and requires a knowledge of the parallax. The *linear velocity* is the linear motion expressed in kilometres or miles per second: to obtain that with reference to the Sun, at right angles to the line of sight, divide the annual proper motion by the parallax, and multiply by 4.74 for kilometres, or 2.95 for miles.

Space or Peculiar Motion.—A star's space or peculiar motion (also known as Absolute, or Real motion), with reference to the surrounding stellar system, is the resultant of its Radial motion, and its motion at right angles to the line of sight, corrected for the Solar System's motion (p. 23): the corresponding velocity is its *Space-velocity*.

The K-term. If the space-motions of the stars were at random, there should be as many stars with recessional (+) velocities, as there are with approaching (-) velocities. Statistics, however, show a surplus of recessional (+) velocities; this excess over the - velocities is the K-term. Improved data have reduced the original amount.

Cross Motion.—This term denotes a star's angular motion at right angles to the great circle joining the star with the Solar Apex or Antapex: the *Cross Velocity* is the Cross motion expressed in miles or kilometres per second.

Parallactic Motion, also known as 'Secular parallax,' is the apparent displacement of a star caused by the Sun's motion—which displacement is known with ever-increasing accuracy as the years go on. The average distance of any class of stars can be found from their Parallactic motions, but the method is not applicable to individual stars.

Star Drift; Star Streaming.—Sometimes the members of large groups of stars are found to have proper motions similar in direction and amount; Proctor called this *Star Drift*. 'Drift' may also denote the motion of a group of stars relatively to the Sun. *Star Streaming* is Star Drift on a large scale. In 1904, Kapteyn found that the stars, in general, are moving in two favoured directions, which, when corrected for the Sun's motion, are diametrically opposite on the star sphere, and both exactly in the plane of the Milky Way. 60% of the stars belong to Stream I, and are moving towards R.A., 6 hrs. 20 min., Dec. 12° N.; the other 40%—Stream II, which has about half the velocity of the first—move towards R.A., 18 hrs., Dec. 12° S. These points are known as the *Vertices of Star Streaming*. The centre of mass (or rather, of mean position) of the stars in a streaming star group is called the *Centroid*.

A third stream, known as 'Stream O,' practically stationary, consists of the majority of the B-Type stars, which seem to belong to the 'Local Cluster' (p. 27).

Gould's Belt of Bright Stars, the nearer or brighter stars of the Local Cluster (which includes the Sun), is a great-circle belt of bright stars which is inclined some 20° to the Galactic Plane: its equator is (roughly) a line drawn from γ Cassiopeiæ between ϵ and β Orionis, ϵ Velæ and δ Carinæ, α and β Centauri, α and ϵ Scorpii, back to the start, passing some 9° S. of α Ophiuchi and *Vega*, and close to δ Cygni.

Star Magnitudes.—The brightest stars are said to be 1st magnitude; those less bright, 2nd magnitude; those still less bright, 3rd magnitude, and so on. Each magnitude is 2.512 (about $2\frac{1}{2}$) times as bright as the one below it, a standard 1st magnitude star (*e.g.* *Aldebaran*, *Altair*) being 100 times as bright as a standard 6th magnitude star, which is about the faintest 'lucid' star, *i.e.*, visible to the naked eye. As, however, several 1st magnitude stars are much brighter than *Aldebaran*, the range of magnitudes also runs in the other direction, a star of magnitude '0' being about $2\frac{1}{2}$ times as bright as one of magnitude 1, and a star of magnitude *minus* 1, about $2\frac{1}{2}$ times brighter than one of magnitude 0, and so on. After magnitude 6, the magnitudes run on, 7th, 8th, &c., for the telescopic stars, the 11th magnitude being about the faintest visible in a three-inch telescope, and the 18th, in the most powerful telescopes yet constructed; stars several magnitudes fainter are obtained by photography. (See Table of relative brightness, p. vi).

Intermediate magnitudes are denoted in tenths or even hundredths, thus magnitude 3.00 is slightly brighter than 3.01, but less bright than 2.99, the magnitude increasing as the brightness decreases. On the *minus* side of 0.0, however, this is reversed, the magnitude figure increasing with the brightness. Thus magnitude -0.1 is brighter than 0.0; -1.0 is brighter than -0.9; and -1.9 is brighter than -1.8, and so on. Where there is no sign, magnitudes are always understood to be +, but + is usually given in the case of 'absolute magnitudes' (see p. 13). In the general sense, '1st mag.' usually means all stars brighter than mag. 1.5; '2nd mag.' those between 1.5 and 2.5. The magnitudes in modern catalogues are *always calculated for the zenith*: at lower altitudes atmospheric absorption diminishes the brightness, and has to be allowed for when comparing stars at different altitudes: see Table, page 36.

Numerical Ratios of Magnitude.—On the 2.512 times basis of reckoning each magnitude, every difference of 5 magnitudes means a multiplication or division by 100 of the starting magnitude, thus 1st magnitude is 100 times brighter than the 6th; 10,000 times brighter than the 11th, and a million times brighter than the 16th, while magnitude 0.0 is 100 times brighter than magnitude 5. This "stellar magnitude" method of comparison is now used for other comparisons than its original one of visual brightness—as for stellar heat-radiation, and even for temperatures.

If the stars were uniformly scattered through space, there would be 3.98 times as many stars of a given magnitude as in the one just above it; departure from this number (called the *star ratio*) indicates crowding, or, thinning out.

The 2.512 scale, now the standard, was introduced by Pogson in 1850, 2.512 being the 5th root of 100, or the logarithm 0.4. Boss's *P.G.C.*, 1910, employs an older system with a light-ratio 2.291 ($\log = 0.36$), approximately that of Argelander's *Uranometria Nova*, 1879. Boss and Pogson magnitudes are the same about mag. 3.8; below* 3.8 Boss is fainter, mag. 6.0 Pogson being about 6.2 Boss. Above* mag. 3.8, Boss is brighter, *Vega* being 0.0, *Sirius* -2.0, Boss; against 0.14 and -1.58 Pogson.

International Magnitude Scale.—Though based on the same light-ratio, the magnitudes found at Harvard, Mount Wilson, Potsdam, &c., show small systematic discrepancies, due to the instruments, atmosphere, &c. Thus for accurate comparisons, each must be 'reduced' to the scale with which it is to be compared, by means of Tables prepared by laborious analysis (see *Harvard Annals*, Vol. 14, and *Astrophysical Journal*, Vol. 61). The Harvard (photometric), and Mt. Wilson (photovisual) Scales are most generally used, and the former was adopted (1922) as the basis of *International Magnitudes*—a photographic Scale. Taking the stars of Type A0 between mags. 5.5 and 5.5, in the Harvard *North Polar Sequence* (a list of carefully-measured stars near the N. Pole arranged in order of photographic magnitude), the mean International magnitude of these stars is defined as being the same as the mean magnitude of these stars on the Harvard visual (photometric) scale—which, for Type A0, is identical with the Harvard photographic scale.

Visual or Apparent Magnitude is the brightness as directly estimated by the eye; when the brightness is measured instrumentally by the photometer, it is called the *Photometric* magnitude.

Photovisual Magnitudes are obtained photographically, using a colour screen and isochromatic plates adjusted approximately to the light-sensitiveness of the eye; they tend to be rather brighter than the visual or photometric magnitudes, and are becoming of great importance as they give more uniform results. They minimise both the instrumental and the brightness 'colour equation' difficulties (see above), and the photographic plate and colour screen used seem to make no great difference in the results.

Photographic Magnitudes are those obtained by measuring the diameters of the images on a stellar photograph. For one-half of the stars the results are accordant with the visual magnitudes, but in the other half, owing to the bluer stars being more actinic, and the redder stars less actinic, the blue stars photograph brighter than they are visually, and the red stars fainter, by an amount depending on the spectral Type of the star (p. 14).

Colour Index (contracted, *c/i*) is the difference, in stellar magnitudes, between the photographic magnitude and the photometric (or photovisual) one, the photovisual index tending to be the greater; on the Harvard colour index scale, Type A0 has *c/i* 0.00, its visual and photographic magnitudes being the same. Colour indices greater than 2.0 are probably very rare; S Cephei, Type Nc, has the very great colour index +5.5. (Colour Index Table opposite).

Photographic Magnitude minus the *c/i* = photometric magnitude. Photometric Magnitude plus the *c/i* = photographic mag.

Colour Index = photographic mag. || Thus ϵ Orionis, Type B0, visual mag. 1.75, *plus c/i* -0.31 = photographic mag. 1.44.
minus the photometric mag. || *Betelgeuse*, " M0, " 0.92 " +1.68 = " " 2.60.

The - indicates that ϵ Orionis is brighter, the + that *Betelgeuse* is fainter, than A0—photographically.

* Used in connection with magnitude, 'above' means brighter than; 'below,' fainter than.

<i>Type of Star.</i>	...	...	O	B0	A0	F0	G0	K0	M	M3	Nc	R	S
Colour Index,	...	...	Giants	-0.32	0.0	+0.38	+0.86	+1.48	+1.88	...	+5.5	...	...
do	...	...	Dwarfs	-0.32	0.0	+0.38	+0.72	+0.99	+1.76	...	...	...	...
Heat Index (average), in Magnitudes	...	...	...	-0.1	0.0	+0.3	+0.7	+1.2	+2.3	...	...	...	...
Surface Brightness,	„	„	Giants	-3.2	-2.3	-1.0	+0.3	+2.3	+4.5	...	...	...	...
do	„	„	Dwarfs	-3.2	-2.3	-1.0	0.0	+1.2	+3.8	...	...	...	...

Luminosity : Surface Brightness.—The luminosity of a star differs from its magnitude in being the *actual* amount of light emitted by the star, instead of the apparent amount, judged by its brightness to the eye. It depends on the star's diameter and temperature, being the star's area (actual, not angular) multiplied by the amount of light it emits per square centimetre, or other unit—i.e., by its *Surface Brightness*. The Sun's surface brightness is taken as mag. 0, and a star's relative surface brightness, + or −, is expressed in magnitudes (Table, p. 13)—symbolised by *J*. The luminosity relatively to other stars is given by the absolute magnitude, or luminosity at 10 parsecs distance.

The higher the temperature, the greater the surface brilliancy; thus stars of the same absolute magnitude may differ greatly in size and surface brightness, for a low-temperature 'Giant' (p. 16) must have a larger diameter than a high-temperature B-star, to be of the same absolute magnitude. From this relationship the diameter of stars can be calculated, independently of their distance, from the visual magnitudes, the surface brightness being obtained from the Type. The diameters that had been predicted on this basis were found to agree closely with the observed values.

Star-classification by their spectra.—Secchi in 1863-67 found that when the light emitted by different stars was analysed by the spectroscope, their spectra fell into four well-marked groups which graded into one another. In 1874, Vogel modified Secchi's scheme by adding two subordinate classes to Class I; another (Wolf-Rayet stars), to Class II; and including his third and fourth types as sub-divisions of the same order. Secchi's Types are now little used, except historically, but for very uncertain cases the I.A.U. defines them as follows (O5 was formerly Oe):—

TYPE I. O5-F5, predominant hydrogen lines. | TYPE III. M, titanium oxide bands. | TYPE V. Oa-Od, bright Wolf-Rayet lines.
 „ II. F8-K5, prominent metallic lines. | „ IV. N and R, carbon bands. |

About 1890, Pickering introduced the 'Harvard' classification, now universally adopted, lettering Secchi's original groups, with others, as in the table opposite, the various sections being spoken of as Type O, Type B, &c. Gradations or intermediates are indicated by combinations of the letters with figures denoting tenth parts. Thus B2 (a convenient abridgment for B2A) denotes a spectrum nearly like that of Class B, but estimated to be two-tenths of the way from B to the following Class A: and O5 (= O5B) means five-tenths of the way from O5 to the next Class, which is B, as Type O is the first in sequence. Type R was added in 1908; and S in 1922. Secchi's classes were based on visual spectra, the Harvard on photographic ones, but, on the whole, they are fairly accordant.

B0 is the highest of Class B (the '0' is a starting cypher, not a letter), and the sequence is O8, O9, B0, B1, B2, B3, . . . B9, A0, A1, A2, &c.; the scale is thus a descending one. Sub-divisions a, b, c, &c., are used where there is uncertainty as to the details, but numbers are substituted when the necessary information is obtained: 'c' and 'n' stars, however, are not subdivisions, but stars having 'c' or 'n' characteristics (p. 15). Variable stars are now classed at maximum (1922). For the sub-divisions included in a 'Type' when used in the average sense, or in statistical work, see next page. For details of Types O to N, see *H.A.*, Vol. 28; *H.C.* 145; and *Draper Catalogue*, 1924 (*H.A.*, vols., 90-99).

Early and *Late Type* stars denote Types B-A, and K-M, respectively, somewhat inconvenient survivals, in certain respects, of Vogel's assumption that Type I stars were the youngest, and Types III and IV the oldest, before the Giant and Dwarf divisions (p. 16) were known. For the same reason, the *Main Sequence* is the downward progression of increasing redness, O, B, A, F, G, K, M—Types R, N, branching off at G; and S, perhaps, at K5 or M0. Type O may be the last stage of another sequence from Nova through planetary nebula to join Type B at the other end.

Russell Diagram.—This shows very effectively the Giant and Dwarf relationship and the Main sequence, the stars being plotted according to Type (temperature), and absolute magnitude (luminosity). By adding curves representing masses, the Diagram has been extended to exhibit the mass-luminosity relationship as well.

Star Colours.—Colour is an index to physical condition and temperature (p. 17). A list of the mean colour of each Type, and sub-division, is given in Monthly Notices Royal Astron. Society, Vol. 84, p. 22. Oa to Oc are given as greenish yellow; B2, B3, white; A0, pure yellow; A5, yellow; K2, orange yellow; M0, orange; R, orange red; Nc, deep orange red: intermediate types merge into the next colour. Colour also affects twinkling, as explained on page 30. The components of many double stars exhibit the curious phenomenon—sometimes merely optical—of being complementary in colour—orange and blue, or crimson and green, &c: for examples, see Notes Star Charts.

Relative Numbers of different Types (Shapley)—Of the 225,000 stars, to about mag. 10, in the Draper Catalogue, only some 2000 are of other types than B, A, F, G, K, M. Nearly 60,000 are brighter than about mag. 8½: 20,000 are essentially identical with the Sun, and 95 per cent are probably within 3000 light-years of us. A and K are most common in the Milky Way.

Type	...	O	B	A	F	G	K	M	N	R	S
<i>Types included</i>	...	...	(B0-B5)	(B8-A3)	(A5-F2)	(F5, G0)	(G5-K2)	(K5-M8)	...	...	...
No. of Stars	...	...	3,567	64,259	21,120	46,552	73,208	13,864	...	...	...
Percentage; to Mag. 6½	...	...	10.9	30.5	10.4	9.9	30.1	8.1	...	...	...
„ „ „ 8½	...	...	2.5	26.7	11.0	16.7	35.4	7.6	...	...	...

The Harvard (Draper) Spectral Classes.—The Table below gives the salient features: the Roman numerals indicate Secchi's Classes (p. 14). The temperatures are those for a 'black body' (p. 17), and are more or less approximate, those below Type G (Sun = G0) being probably rather low. For the Radial velocity of each Type see page 16. Be, Me, Se, Oe, &c., stars denote B, M, S, O, &c. stars having bright emission lines.

'Type B,' 'Type A,' &c., when used in the general sense, or in statistical work, does not usually mean the series B0 to B9, or A0 to A9, but an *average* Type, in which A0, B0, &c., are approximately central, including the latter half of those lettered in the Type earlier, just as '2nd. magnitude' is not 2.0 to 2.9, but 1.5 to 2.5, or 1.6 to 2.5. Shapley's Table, opposite, indicates an (approximate) usual basis, but there is no definite rule: some begin Type B with O5.

- V. TYPE O. WOLF-RAYET STARS (Greenish-white). Very high temperatures, large masses and velocities: bright bands in their spectra indicate connection with planetary nebulae and final stage of Novæ. All in Milky Way, or Magellanic Clouds. Subdivisions Oa, Ob, Oc, Od (Wolf-Rayet stars proper); and Oe, abolished 1928, O5-O9 being substituted, with Wolf-Rayet bands described by affixing a, b, c, d, as Oeb. (35,000° K., 62,000° F.). γ *Velorum*.
- I. TYPE B. ORION or HELIUM STARS (Bluish). Helium lines prominent: very brilliant and hot: large masses; mean density 1/10th Sun's. Very distant: small proper motions and mean velocities: strong Galactic concentration; brightest mostly belong to Local Cluster; great globes of glowing gas. (25,000° K., 44,000° F.). ϵ (B0), δ , ζ *Orionis*; β *Crucis*.
- TYPE A. SIRIAN or HYDROGEN STARS (White). Balmer Hydrogen lines very intense, Helium absent. Most numerous Type after K. Predominate in low galactic latitudes. Greater proper motions than B. (11,000° K., 20,000° F.). *Sirius* (A0), α *Andromedæ*, β *Carinæ*.
- TYPE F. SIRIAN-SOLAR or CALCIUM STARS (Yellow-white). Calcium H and K lines very prominent: Hydrogen lines much less intense, metallic lines increase. Much less numerous than A, but includes majority of known binaries, and large-proper-motion stars; little Galactic concentration. (7500° K., 12,200° F.). *Canopus* (F0), γ *Bootis*, α *Hydri*.
- II. TYPE G. SOLAR STARS (Yellow). Hydrogen lines narrower and still less intense; H and K calcium lines prominent, and many fine, dark lines in spectra. Density of Dwarfs about $1\frac{1}{2}$ times that of water. Move more rapidly than preceding types. Little Galactic concentration. (6000° K., 10,000° F.). *Sun*, *Capella*, (G0); α^1 *Centauri*, β *Hydri*.
- TYPE K. ARCTURIAN or RED-SOLAR STARS (Orange-yellow). Hydrogen lines fainter, hydrocarbon bands appear; density of Giants about 1/10,000th Sun's: most numerous type, predominate on the whole in low galactic latitudes. (4200° K., 7000° F.). *Arcturus* (K0), α *Ursæ Maj.*; α , β , *Indi*.
- III. TYPE M. ANTARIAN STARS (Orange). Spectra like that of the Sun, but with broad titanium oxide and calcium bands or flutings. Density of Giants less than 1/20,000th of Sun's; of Dwarfs, greater than Sun's. Very distant: higher mean velocities than B to K, in all directions; widely scattered. Fainter stars show a preference for the galactic centre (Sagittarius region). Sub-classes were Ma, Mb, Mc, Md (bright lines): Md was abolished 1922 (the 'emission' sign 'e' suffices), the others were made M0, M3, M8. (3000° K., 4900° F.). *Betelgeuse* (M0), *Antares*, *Mira*.
- IV. TYPE N. CARBON STARS (Deep orange-red). Peculiar band spectra like those of comets and candle-flames, due to carbon compounds; two-thirds in or near Milky Way. Probably in a branch sequence, G, R, N. Sub-classes Na, Nb, (made N0 and N3, 1922), and Nc, the deepest red of all the stars (as *S Cephei*). (2600° K., 4200° F.). *Y Canum Ven.*, [*U Hydriæ*, 19 *Piscium*].
- TYPE P. Used for gaseous nebulae. (For details see *H.A.*, vol. 28).
- TYPE Q. Used for Novæ. Divided meanwhile (1928) into Qa, Qb, Qc, Qd, Qu, Qx, Qy, Qz; the last has weak Wolf-Rayet lines, but, unlike those before it, no bright hydrogen bands. (See page 39; and *Trans. I.A.U.*, 1922, 1928).
- TYPE R. (Orange-red). Carbon bands; visually resembles N, but photographically different, blue and violet being brighter; not so red as M or N: brightest, mag. 7. Probably joins main sequence at G, the branch sequence being G, R, N. Added 1908 (*H.C.* 145); mostly in N previously. (2300° C., 4500° F.). *B.D.* - 10° 5057 (R0), *C.D.* - 24° 12084.
- TYPE S. Red stars. Mostly long-period variables; very complicated spectra, bright hydrogen lines, absorption and emission lines, and some zirconium oxide absorption bands; perhaps a branch from K5 or M0. Added 1922; mostly in N previously. (See a list *Mt. W. Contr.* 252). ... π^1 *Gruis*, *R Andromedæ*, *R Cygni*.

Notation for Peculiarities.—There are two sets of notations, one prefixed, the other affixed to the Type; 'earlier' means in the Type B direction; 'later', in the M direction. (Full list and details, *Trans. I.A.U.*, 1922, 1928).

Prefixed.

- c Denotes all lines normally narrow and sharp, and (later than B0), the hydrogen lines and enhanced lines abnormally strong. (Not used earlier than B0).
- g Giant Stars (not used earlier than F0). Denotes enhanced lines fairly strong; low-temperature lines relatively weak; hydrogen lines strong.
- d Dwarf Stars (not used earlier than F0). Denotes enhanced lines weak, and certain calcium and titanium lines strong.

Affixed.

- v Indicates a variable spectrum.
- s Lines sharp, but 'c' characteristic not present.

Affixed, contd.

- e Bright emission lines, except in P, Q: remarkable, e!
- eq *do.*; with absorption line on the violet side.
- er *do.*; bright lines conspicuously 'reversed', dark centre.
- em Bright hydrogen & fairly conspicuous bright metallic lines.
- ew Wolf-Rayet emission lines or bands: conspicuous, ew!
- k Stationary hydrogen and calcium lines.
- n Denotes lines unusually wide or diffuse.
- p Peculiarities. p! remarkable peculiarities. Symbol of the element most affected is given in parenthesis (Unidentified lines 'Un.').
- [] Forbidden lines; symbol of element in square brackets.

Giant and Dwarf Stars.—Spectral type indicates the temperature; temperature regulates the surface brightness; and the surface brightness of a star multiplied by its area gives the luminosity or total amount of light emitted. This, again, regulates the absolute magnitude. Hence when two stars of similar Type have different absolute magnitudes, they must have different light-emitting areas, and diameters. This is well shown on a *Russell Diagram* (p. 14).

Analysis of absolute magnitudes shows that on the one hand there is a continuous series of stars from Types M to B, with increasing temperatures, which have great and fairly constant absolute magnitudes, ranging from about +1.0 to -2.0, or about three magnitudes. On the other hand there is a reversed series from A to M, with decreasing temperatures, and absolute magnitudes falling off a magnitude or two as each successive Type below is reached.

Stars of the increasing-temperature series are known as *Giants*, those of the decreasing-temperature one as *Dwarfs*, because the Giant M-stars must have enormous diameters to appear as bright as they are with their low temperatures, while the Dwarf M-stars must be small in diameter to appear as faint as they are, with similar temperatures. These names, however, only apply literally to the M or late K stars of the two branches, as the difference in diameter between each branch continually lessens with each step forwards or backwards towards A and B, until, in these Types there is little or nothing to distinguish the members of each series: from F0, however, Giants and Dwarfs can be distinguished by their 'enhanced' and 'low temperature' lines (p. 20), the Giants having a lower temperature than the corresponding Dwarfs. *Super-giants* are those with absolute magnitudes greater than about -2.0, like *Betelgeuse*. The Dwarfs greatly out-number the Giants; the cooling stage probably lasts much longer.

The *White Dwarfs*—exceptional stars like the companion of *Sirius* (*Sirius B*)—are stars of high temperature, yet so very faint that their diameters must be very small and their density almost incredible—50,000 times that of water, or more, their more or less electron-stripped atoms being packed enormously closer than in the matter we know.

Star Masses and Densities.—A star may be born a Dwarf in size if its mass is much below the average, for apparently the mass of a star determines how high its temperature will rise, only those of great mass attaining Type B, and those of very great mass Type O, while those of very small mass may just rise to visibility as M stars, and then pass out of sight again as they cool, in accordance with 'Lane's Law' that a gaseous body radiating heat, and contracting under its own gravity, must get hotter as long as it behaves as a perfect gas. This law alone, however, does not explain all the facts, and the enormous amount of radiation poured forth by the stars for ages. It is now believed that as a star grows older its mass decreases, mass being converted into energy.

Star masses, as yet, are only known directly in the case of binaries, the average binary system having about 1.8 times the Sun's mass (contracted, 1.8 $\odot$); halving this, gives the average individual star mass as 0.9, or nearly that of the Sun. The mass of non-binary stars* is roughly calculable from spectrum and luminosity, as stars plotted according to mass and absolute magnitude (luminosity) lie along a smooth curve, on the whole—the *mass-luminosity* relationship.

Masses five or six times that of the Sun are not common, and no mass less than that of Krueger 60B, about 1/6th of the Sun's, is known. The greatest known masses are the components of a mag. 6 Oe binary, *Plaskett's Star* (B.D. 6, 1309, combined absolute mag. -6.3), at least 86 and 72 times the mass of the Sun.

Giant M-stars have very small density, less than that of air, being only some 1/10,000th to 1/20,000th of that of the Sun, which is 1.42 times that of water; to make up, their diameters are of the order of 100 to 500 million miles. At the other extreme are the White Dwarfs; *Van Maanen's Star*, the densest known, is absolute mag. (visual) 14.4, from which it is estimated that it is about the size of the Earth, and some 300,000 times as dense as water.

Star Velocities are best known through the radial velocity, as it can be found with considerable accuracy, and gives the minimum-possible value for the 'space' or real velocity, which, in general, must be greater, but is known less accurately, its other factors of parallax, proper motion, and solar motion, being more or less uncertain. The space-velocities cannot, however, differ greatly from the radial ones, unless the cross velocity is relatively great. As cross velocities, on the average, apparently do not differ greatly from the radial ones, the average space-velocity may therefore be taken to be of the order of $1\frac{1}{2}$ times the radial velocity, i.e. the approximate resultant of two equal velocities at right angles. Velocities are expressed in kilometres or miles per second (contracted, 'km./sec.', m./sec.).

The majority of star velocities are under 30 kilometres (19 miles) per second, those of 50 km. (31 miles) are not common; but there are notable exceptions, RZ Cephei having the enormous velocity of 1100 km. (680 miles) per second. This is far surpassed by the spiral nebulae, which speed through space with velocities approximately proportional to their distance (about 500 km./sec. or 300 m./sec. per megaparsec), up to some 150 million light-years or more, for which the corresponding speed is 1900 million kilometres or 1200 million miles per day.

On the average, velocities tend to increase with advancing Type, as shown by the Table of approximate average radial velocities (*Campbell, &c.*) below: the velocity also increases as the absolute magnitude increases. The velocities of the few R stars known, fall into three groups; under 10 km./sec., about 40 km./sec., and high velocity 250-380 km./sec.

Radial Velocity:—	Type	O	B	A	F	G	K	M	Me	N	R	Se	P
Km. per sec.	...	25½ km.	6½ km.	11 km.	14½ km.	15 km.	16½ km.	17 km.	35 km.	18 km.	21 km.	24 km.	30 km.
Miles per sec.	...	16 miles	4 m.	7 m.	9 m.	9 m.	11 m.	11 m.	22 m.	11 m.	13 m.	15 m.	18½ m.
Mean abs. mag. (Dwarfs)		-4.5	-2.4	+0.6	+2.6	+4.4	+6.2	+9.8	...	...	...	...	(gaseous nebulae)
" " (Giants)					-0.6	+0.3	+0.6	0.0	-0.5	(-1.5)	(-1.5)	(+0.4)	

* But not White Dwarfs.

Star Diameters.—The angular diameters of the stars are far below the limit of direct angular measurement, but, in 1921, interferometer measures showed that *Betelgeuse*, *Antares*, *Arcturus*, and later, *Mira*, have angular diameters of .047", .040", .022", and .056", corresponding to 217-, 400-, 21-, and 125 million miles respectively, less or more, according to the parallax adopted. (The mileage for any parallax may be found by the simple rule given below). *Betelgeuse*, however, apparently pulsates, varying from 0".034 to 0".047. Stellar diameters can also be calculated on the basis of surface brightness and visual magnitude (see 'Luminosity').

Diameter in Miles.—Multiply the angular diameter in seconds of arc by 93,000,000, and divide answer by the annual parallax.

„ Kilometres.— „ „ „ „ „ 150,000,000, „ „ „ „ „

Stellar Rotation.—In some spectra all the lines are equally wide, mostly faint, and fairly sharp-edged; the metallic lines being wide, the Stark effect cannot be responsible. The wide lines are interpreted as being due to the stars' rapid rotation, the widening being the effect of the lines produced by each limb, which are displaced in opposite directions. The most rapid rotation yet found is that of *Altair*, 260 km./sec. (160 m./sec.), which rotates in about 7 hrs., although its diameter is about $1\frac{1}{2}$ times that of the Sun. Smallest velocity detectable, about 30 km./sec.

Star Temperatures.—Spectral Type is chiefly a temperature phenomenon, and stellar temperatures can be measured by analysis of the 'energy distribution' in their spectra—that is, by ascertaining the point at which the intensity is greatest: the further the maximum intensity is towards the violet end, the higher is the temperature.

A star temperature so found, however, is not that of the interior (which in the Main Sequence is of the order of 40 million degrees K.), or of the surface, but is what is called the *Black Body* or *Effective Temperature*, which may be defined as the temperature of a 'perfect radiator' (say that of a sheet of lampblack, the nearest approach to it) which sends out the same amount of radiation per unit of area as that emitted by an equal area of the star. This is based on 'Stefan's Law'—viz., that the total radiation is proportional to the 4th power of the absolute temperature (see below), multiplied by a constant depending on the nature of the radiating surface. For the approximate effective temperatures of each Type, see p. 15. The White Dwarfs have central temperatures of the order of hundreds of millions of degrees K. the M Giants, only some four or five million degrees K.

The Absolute Temperature is the temperature above *Absolute Zero*, the temperature of a gas containing no heat, $-273^{\circ}\text{C}.$,

($-460^{\circ}\text{F}.$); it is usually stated in degrees 'K' (Kelvin) which is just the ordinary Centigrade temperature *plus* $273^{\circ}\text{C}.$

Stellar Equipartition of Energy.—While there are considerable differences in the velocities of individual stars in each Type, stars of low velocity, *on the average*, have large masses, and those of high velocity small masses. The kinetic energy of each star—the velocity² multiplied by half the mass—is also, on the average, approximately a constant quantity. This has been shown to result from the inter-action of the stars on one another over enormous periods. The B stars, however, do not conform to the rule.

Star Counts or Gauges, originated by Sir W. Herschel, are used for ascertaining the distribution of the stars on the star sphere. A number of representative areas are selected; the stars in each are carefully counted, and their positions, magnitudes, proper and radial motions, spectra, and parallaxes, ascertained, so far as is possible. A Table of the number of stars of each magnitude, per square degree, is given in the B.A.A. Handbook for 1926.

Kapteyn's Selected Areas, a great photographic Star Count of some 250,000 stars (limiting mag. 16, International), had, as planned, 206 representative areas, each 75' square, or circles 42' in radius, on or near the circles of N. and S. Dec. 0° , 15° , 30° , 45° , 60° , 75° , 90° ; also 46 Milky Way areas: this, however, proved too onerous for rich regions, and some areas were restricted thus—Galactic longitude N. and S., 0° - 20° , $40' \times 40'$; 20° - 40° , $60' \times 60'$; 40° - 90° , $80' \times 80'$.

Light-Absorption in Space seems to be negligible, as the distances derived from the brightness and diameter, respectively, of the remotest spiral nebulae are fairly accordant. Near the Galactic Plane, however, evidence favours a slight absorption, which results in absolute magnitudes being less than they should be, and distances derived from them too great. Assuming an absorption of 0.7 mag. per 1000 parsecs, at 500 parsecs the real distance would be 14% less than the apparent; at 1000 parsecs, 24% less; & 5000 parsecs, 56% less; but later evidence favours a smaller absorption.

Centigrade Degrees converted into Fahrenheit Degrees (approximate: for exact equivalent, add $32^{\circ}\text{F}.$).

C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o	C. ^o	=F. ^o
500	900	2500	4500	4500	8100	6500	11700	8500	15300	11000	19800	15000	27000	19000	34200	23000	41400	28000	50400
1000	1800	3000	5400	5000	9000	7000	12600	9000	16200	12000	21600	16000	28800	20000	36000	24000	43200	30000	54000
1500	2700	3500	6300	5500	9900	7500	13500	9500	17100	13000	23400	17000	30600	21000	37800	25000	45000	35000	63000
2000	3600	4000	7200	6000	10800	8000	14400	10000	18000	14000	25200	18000	32400	22000	39600	26000	46800	40000	72000

'K' Degrees converted into Centigrade and Fahrenheit Degrees (to nearest 100° , more exactly, add $27^{\circ}\text{C}.$, $40^{\circ}\text{F}.$).

K. ^o	=C. ^o	=F. ^o	K. ^o	=C. ^o	=F. ^o	K. ^o	=C. ^o	=F. ^o	K. ^o	=C. ^o	=F. ^o	K. ^o	=C. ^o	=F. ^o	K. ^o	=C. ^o	=F. ^o	K. ^o	=C. ^o	=F. ^o
500	200	400	3500	3200	5800	6500	6200	11,200	11,000	10,700	19,300	17,000	16,700	30,100	23,000	22,700	40,900			
1000	700	1300	4000	3700	6700	7000	6700	12,100	12,000	11,700	21,100	18,000	17,700	31,900	24,000	23,700	42,700			
1500	1200	2200	4500	4200	7600	7500	7200	13,000	13,000	12,700	22,900	19,000	18,700	33,700	25,000	24,700	44,500			
2000	1700	3100	5000	4700	8500	8000	7700	13,900	14,000	13,700	24,700	20,000	19,700	35,500	30,000	29,700	53,500			
2500	2200	4000	5500	5200	9400	9000	8700	15,700	15,000	14,700	26,500	21,000	20,700	37,300	35,000	34,700	62,500			
3000	2700	4900	6000	5700	10,300	10000	9700	17,500	16,000	15,700	28,300	22,000	21,700	39,100	40,000	39,700	71,500			

Planetary Radiation.—A planet radiates (*a*) reflected solar radiation of short wave-length, *i.e.*, the visible and actinic rays: (*b*) *Planetary Radiation*, of long wave-length, *i.e.*, invisible heat-rays, emitted from the planet's surface. (*b*) is thus the measured total radiation *less* the amount of (*a*). As an atmosphere acts as a blanket to a planet, the planetary radiation of atmosphereless planets will be high, while that of those with atmospheres will tend to be small.

Jupiter and Saturn emit 6 per cent of planetary radiation; Mars has about 50%, indicating a thin atmosphere; Venus, about 8% on the bright side. The Moon and Mercury give 74%, suggesting similar physical (atmosphereless) condition. The Moon's local radiation at first or last quarter is proportional to the distance from the illuminated limb, and is zero at the terminator. The difference in the radiation from the light and dark lunar areas is slight.

Planetary Temperatures.—The surface-temperature of the Moon varies greatly throughout the lunar day; under the vertical Sun it is 101°C. (214°F.), while during the long night it sinks to less than -150°C. (-240°F.). *Mercury* under the vertical Sun is about 665°K. (392°C., 738°F.), about the melting point of lead; his dark side must be very cold, practically no heat being measurable. *Venus* differs little on the bright and dark sides, her temperature being about -23°C. (-9°F.); we evidently only see the upper surface of a cloud-layer in the isothermal region. *Mars*, under the vertical Sun, is 21°C. (70°F.) at perihelion, but only -6°C. (21°F.) at aphelion. Jupiter and the other giant planets are evidently cloud-covered like Venus, but their temperatures are lower, Jupiter and Saturn being some -100° to -75°C. (-150° to -100°F.), the others some -150°C. (-240°F.).

Bode's Law.—A curious relation between the distances of the planets from the Sun, for which no reason is known. Taking Mercury as 4, adding 4 to each term of the geometrical series 3, 6, 12, 24, &c., gives the approximate distances of the planets up to Uranus, but not Neptune's. Pluto is very near the position Neptune should occupy. Bode remarked that a planet was missing at the distance where the asteroids have since been discovered.

Planet	Mercury	Venus	Earth	Mars	Asteroids	Jupiter	Saturn	Uranus	Neptune	Pluto
Geometrical Series	3	6	12	24	48	96	192	384	768	
Add	4	4	4	4	4	4	4	4	4	4
Distance fr. Sun, Bode's Law	4	7	10	16	28	52	100	196	388	772
„ „ Actual	3.9	7.2	10	15.2	27.4	52	95.4	192	301	395
Angular Diameter Max.	12''9	64''0	...	25''1	...	49''8	20''5	4''2	2''2	...
„ „ Min.	4''7	9''0	...	3''5	...	30''5	14''7	3''4	2''4	...
Inclination of Axis*	...	...	23°45	25°17	...	6°11	26°7	98°	151°	...
Mass, Earth=1	0.04	0.81	1.00	0.108	...	316.94	94.9	14.66	17.16	0.66?

NOTES ON SOME TERMS USED IN ASTRONOMICAL TABLES.

The following terms are frequently met with in astronomical literature; a full explanation is quite beyond the scope of this work, but details will be found in Young's Revised Astronomy, Vol. I. (Russell, Dugan, and Stewart).

Interpolation; Extrapolation.—Interpolation is the process of finding values for dates, hours, quantities, &c., intermediate to those given in a Table. For ordinary purposes, the proportional amount of the difference between the figures for the two nearest dates, quantities, &c., usually suffices, it being assumed, for simplicity, that the change in the interval is uniform; a more accurate result, useful when maximum or minimum occurs between the dates, is obtained by plotting on squared paper several successive dates, &c., on each side of the one not given, and drawing a curve through these points.

Extrapolation, a similar process, extends a series of figures beyond the limit of the last figure actually known; there being only one limiting figure, however, it is less simple than interpolation.

Errors of Observation.—These are of two kinds: *Systematic Errors* and *Accidental Errors*, for which see page 13. The former are detected by observations repeated with different instruments, &c., or by comparison with results obtained by other methods; the latter errors are erratic, but can be allowed for by analysis of the small discrepancies between the individual observations of a series, or between observed and calculated values—which discrepancies or differences are known as *Residuals*.

The Probable Error (P.E.), of a series of observations is a value derived mathematically from these residuals; it affords an index to the reliability of the figures given, and is prefixed by the sign $\pm$, which means that it is an even chance whether, by the amount of the probable error, the value given is greater, or less. The smaller the probable error, the greater the reliability.

Method of Least Squares.—A method used to ascertain the most probable mean value derivable from a number of different observations. It is based on the principle that the 'weights' (degree of accuracy) of observations, with different probable errors, are inversely proportional to the squares of their probable errors.

Contracted Notation employs the factor '10,' with small index figures, to express large numbers in a small space. The index figures may be taken as indicating the number of ciphers to be added after the 1. A *minus* before the index figures indicates a fractional number, *viz.*, 1 divided by that number; thus $10^{-6} = 1/1,000,000$ th or '000001, from which it appears that *minus* index figures show the position, *after* the decimal point, of the first significant figure of the decimal fraction, the number of ciphers before the 1 being *one less* than the index number. Note that the factor not containing the 10 is *always between 1 and 10*, thus 1.23×10^6 is correct, not 123×10^4 as shown in the example to illustrate the working out: the index of 10 (whether + or -) is then the 'characteristic' of the logarithm of the number. The following are examples with decimal factors:—

$1.23 \times 10^6 = 1,230,000$	or $123 \times 10^4 = 1,230,000$	$1.23 \times 10^{-6} = 1/1,000,000$	or $123 \times 10^{-8} = 123 \times '00000001 = '00000123$.
$10^1 = 10$	 = 1 with 1 cipher after it	$10^{-1} = 0.1$	 = 1 in the 1st place after decimal point.
$10^3 = 1000$	 1 " 3 ciphers "	$10^{-2} = 0.01$ (1/100th)	" " 2nd " " "
$10^6 = 1$ million	 1 " 6 " "	$10^{-6} = 0.000001$ (1/millionth)	" 6th " " "
$10^9 = 1$ billion (U.S.A., &c.)	1 " 9 " "	$10^{-9} = 1/\text{billionth}$ (U.S.A.)	" 9th " " "
$10^{12} = 1$ billion (British)	 1 " 12 " "	$10^{-12} =$ " (British)	" 12th " " "

* From the perpendicular to the orbit.

Flame, Arc, and Spark Spectra.—The lines produced by each element are not the same under all circumstances, being changed or modified under different conditions of temperature, pressure, &c., especially the former. The *Flame*, *Furnace*, or low-temperature spectrum given in a Bunsen burner (some 2000° C.) has comparatively few lines, and differs in some respects from that of the *Arc* spectrum obtained in the electric arc at a temperature of some 3600° C., in which new lines may appear. The *Spark* spectrum, again, produced by high tension discharges, has different characteristics from that of the arc, some 'low-temperature' lines, that have been fading as the temperature rose, disappearing altogether, while other lines are 'enhanced,' that is, have grown more intense. Spectra can be studied up to temperatures of some 20,000° C., by electrically-exploded wires.

Enhanced Lines are due to the normal atoms (see below) becoming 'ionised'—that is, losing one or more electrons as the combined result of higher temperature and altered pressure (*Saha Effect*); each element has its own ionisation conditions, thus the presence (or non-presence) of certain lines in stellar spectra affords a clue to the physical conditions in the stars' atmospheres.

Forbidden Lines are produced by possible, but very unlikely, 'transitions' (see below) in the atom; an electric field, however, cancels the prohibition, and with a field of sufficient strength the lines become visible. The appearance of forbidden lines in a star's atmosphere indicates that it is dense, the electric field being due to the close ionised atoms and free electrons.

Zeeman Effect.—If a magnetic field is present, lines normally single may split up into two or more lines—from which the polarity of sunspots, and the position of the Sun's magnetic axis are found.

Doppler Effect, or the displacement of the lines as the result of motion of the light-source in the line of sight, is of great importance, as it enables radial velocities and rotation periods to be found, and spectroscopic binaries to be discovered. If a source of light is approaching the observer, any lines seen in its spectrum will not be in their normal positions, but some distance nearer the violet end of the spectrum, or nearer the red end of the spectrum if the light-source is receding. As the displacement is proportional to the velocity, the radial velocity can be calculated by identifying a series of lines and measuring the amount of shift.

In the case of a binary star, each star produces its own set of lines; when both stars are in the line of sight, the two sets are super-imposed and appear as a single set, there being no orbital radial motion, as their motions are at right angles to the line of sight. But when the stars open out again, one star is moving towards us, and the other away from us, so that the two sets of lines separate in opposite directions, and reveal the duplicity, and the respective orbital radial speeds; the same principle applies to the opposite limbs of the Sun, of a rotating planet, or of a star (p.17), one of which is moving towards us, the other from us.

Sometimes in Novæ and in B and O type stars a third set of practically stationary lines appears, suggesting the presence of a cloud of calcium vapour between us and the star (see p.30).

Stark Effect.—The splitting up of lines by an electric field; those of helium and hydrogen are greatly affected, those of the metals but little; thus it can be distinguished from the Zeeman effect. The hazier the helium and hydrogen lines, the stronger is the electric field, and the more prominent the forbidden lines; also the denser the stellar atmosphere must be, to give the electric field required to allow the forbidden lines to be produced in quantity. (See also Stellar Rotation, p.16).

The Atom and its Properties.—The varied stellar spectra, and most of the above 'effects', are due to internal changes in the atoms of the elements in the stellar atmospheres, under different temperature and pressure conditions; the following main facts underlie the various phenomena, on Rutherford and Bohr's theory—which, however, by no means accounts for all the facts.

Atoms.—The atom of an element is the smallest particle distinguishable by chemical means; though the atoms of each element differ in weight and properties, all are built up of the same three fundamentals—protons, electrons, and energy.

Each proton is a constant positive charge of electricity; each electron an equal negative charge. In the normal atom, these charges balance, and there being no electric field, in this condition the atom is known as a *neutral atom*.

The energy component of an atom is stored up in what may be popularly described as 'energy-atoms,' as they cannot be sub-divided. Each 'energy-atom' is known as a *Quantum* (plural quanta), and represents energy equivalent to that of radiation of some particular wave-length, quanta of long wave-length having small energy, those of short wave-length, great energy; there are quanta corresponding to all wave-lengths. 'Short' wave-length, as a general term, spectroscopically denotes the wave-lengths at and beyond the blue end of the spectrum; 'long' wave-length, those at and beyond the red end. The conventional divisions of wave-length are as follows (the boundaries between are indefinite, each kind gradually merging into the other: λ =angstroms).

Hertzian (Radio)	Infra-red (Invisible)	Red Light (Visible) from:	Violet Light (Visible) to:	Ultra-violet (Invisible), to:	X-rays (Invisible)		γ -rays (Invisible)	
25,000 metres to 0.1 "	from 0.03 cm. to λ 7600	0.000,076 cm. λ 7600	0.000,039 cm. λ 3900	0.000,001.4 cm. λ 140	Soft, to: 0.000,000.2 λ 25	Hard, to: 0.000,000,001 cm. λ 0.1	Soft, to: 0.000,000.04 λ 4.0	Hard, to: 0.000,000,005 cm. λ 0.05

Cosmic (invisible), 0.000,000,000,004 cm. (λ 0.0004).

Each element has its own particular quanta of energy, corresponding to those wave-lengths of radiation which its atoms emit or absorb under different conditions. Only quanta with nearly these wave-lengths can effect 'transitions' in that kind of atom, but those of shorter wave-length may 'ionise' the atom—i.e., knock off one or more of its electrons (see page 21).

The atoms of a gas, under the action of the heat which it contains, rush about at high speeds, and incessantly collide; the higher the absolute temperature (p.17), the greater their speed, and the more violent the collisions.

In a rarefied gas—i.e., one at a very low pressure—the journey without any collision, or *free path*, of the atom is long, the distance between the atoms being relatively great; collisions are therefore less frequent than in a dense gas.

The amount of short wave-length energy in a gas depends on its absolute temperature; thus, at high temperatures, short wave-length quanta are more plentiful than long wave-length ones. To sum up; in a stellar atmosphere:—

Temperature is an index of (a) the number of atomic collisions per second, for a given pressure; (b) the speed of the atoms; (c) the violence of the collisions; (d) the proportion of short wave-length energy.

Pressure only affects the frequency of the collisions, by increasing or decreasing the distance between the atoms.

The Structure of the Atom.—Atoms are pictured as miniature sun-and-planet systems, consisting of a heavy nucleus—almost inconceivably small, and itself composed of protons and electrons—carrying a positive charge of electricity equal to the sum of the negative charges carried by one or more electrons revolving in orbits round the nucleus; each orbit can only hold one electron. The simplest and lightest atom is that of hydrogen, composed of one proton and one electron; the most complex, and heaviest, is that of uranium, which has 92 electrons revolving round the nucleus.

* i.e., less penetrating than 'hard.'

The K-ring, &c.—The electron-orbits are spaced in groups, each member of which has about the same energy and diameter, but may differ in eccentricity. These groups are known as *Rings*—sometimes, more appropriately, as ‘shells,’ because the members of each group presumably move in different planes, their diameters being about the same.

The group nearest the nucleus consists of two orbits of equal energy known as the *K-ring*, which has the lowest energy of all the rings; next comes the *L-ring*, with eight orbits; then the *M-ring*, with 18 orbits, and so on; the outer ring of an element’s electrons may contain only one electron. The chemical and spectroscopic quantities of an element are largely determined by the number of electrons in its outermost layer; these are also the most easily ‘excited’ or knocked off, (see below).

Transitions.—When all the electrons of a neutral atom are revolving in the orbits nearest the nucleus, the atom is said to be in its *lowest energy* (normal) state. But (a) by a sufficiently violent collision with an electron or another atom, or (b) by encounter with, and absorption of, a quantum of energy of wave-length the same as one of its own fundamental quanta, an atom may undergo *transition*, being ‘raised’ or lifted to a ‘higher level’—i.e., of energy, and from that, it may be, to still higher and higher levels. This absorption of energy results in an electron undergoing transition—i.e., being forced out into an orbit of larger diameter, in accordance with certain laws.

Excitation.—At every transition of an electron to a larger orbit, a quantum of definite wave-length is absorbed by the atom, which is then said to be *excited*: it thus becomes a greater and greater reservoir of energy as the excitation increases; whatever the amount of excitation, however, it still remains a ‘neutral’ atom.

If left undisturbed, an excited atom ‘falls’ back to its lowest energy state in a hundred-millionth of a second, emitting in the process as many quanta of the same wave-lengths as it has absorbed; the process may be accomplished in stages. Certain transitions, however, are *metastable*—that is, if left to themselves, excited atoms in that state may continue in it for hundreds of thousands of times longer than ordinary excited atoms are able to do.

Ionisation.—An electron of a neutral atom may not only be raised to a larger orbit, but may also be completely knocked off, and left to travel on its own account; the atom is then *ionised*, and is no longer neutral, but positively charged, owing to the loss of the negative electron. Ionisation may be caused (a) by a sufficiently violent collision; (b) by encounter with a quantum of short wave-length, with more than sufficient energy to lift an electron to the outermost level.

Atoms vary in the amount of energy required to excite and ionise them, and the amount of energy denoted by 1 (electron-) volt* is taken as the unit of measurement. The number of (electron-) volts required to excite, or to ionise, the atom of each element, is known as its *Excitation* (or *Ionisation*) *Potential*. The ionisation potential of potassium is 4.3 volts; of sodium, 5.1; of calcium, 6.1; of iron, 9.2; of hydrogen, 13.5; of helium, 24.4. To remove a second electron takes, in general, about twice the voltage required for single ionisation, but elements differ widely in the amount required.

Atoms may be singly, doubly, trebly, &c., ionised. The neutral atom is indicated by the chemical symbol of the element with the Roman numeral I affixed, as *Or^I*, neutral oxygen; for singly and doubly ionised, II, III, are added, and so on, as *O^{II}*, *O^{III}*. Ionised atoms can be excited in the same way as neutral atoms.

An older system affixed a small + for single ionisation, + + for double, and so on, instead of Roman numerals, as *O⁺*, *O⁺⁺*; still further back, the atoms causing enhanced lines were known as *protocalcium*, *protomagnesium*, &c.

Ultimate Lines.—Those fundamental lines of an element that alone persist under great rarefaction. When about the region of the spectrum which cannot ordinarily be observed, those that can be observed are known as *Raies ultimes*.

Sets of Lines.—Each state of the atom gives rise to a different set of lines in the spectrum, the neutral atom causing one set, excited atoms other sets, and variously-ionised atoms others still; pressure also affects the appearance of the lines. And in stellar atmospheres of similar composition, for a given temperature and pressure there is always definite proportion of atoms in each state.

The strength of a line is proportional to the number of atoms producing it; strong lines indicate plentiful atoms in that condition, faint lines relative scarcity. Strong lines usually have *Wings*—i.e., shading on both sides.

Contours of Lines.—The degree of blackness at any part of the shading of a winged line, with reference to the background, is known as the *Contour* of the line at that point—so called because the energy-curve obtained by plotting the various intensities according to wave-length and blackness, is analogous to the gradient-curve obtained from the contour lines on a map.

Interpretation of Spectra.—At very low pressures, as in the Giant stars (p. 16), for a given temperature the wave-length energy available is the same, and the violence of collision the same, as in dense stars; excited and ionised atoms are also present in both. But when an atom is ionised, the distances apart in a rarefied gas being great, there is less chance of its recapturing an electron, so that the proportion of ionised atoms is greater, and that of the neutral atoms less; the Giant star will, therefore, have stronger ionised-atom lines and weaker neutral-atom lines, than those in the spectrum of a dense star of about the same temperature; its lines will also be narrow and sharp—the ‘c’ characteristic (p. 15). In dense stars, on the other hand, distances apart being small, ionised atoms soon recapture an electron, thus the neutral-atom lines are strong, the ionised-atom lines faint.

At the low temperature of the furnace spectrum, the lines of the excited atoms are faint (being chiefly those of the more-easily excited elements), while those of the normal (lowest energy-state) atoms are strong, the proportion of the latter atoms being the greatest. With rising temperature, owing to the more violent collisions and the greater supply of short wave-length quanta, the excited-atom lines grow stronger, owing to the ever-increasing quantity of atoms in that condition, and at last, at the arc spectrum temperature, ionised lines of the easily-ionised elements also begin to appear—some even appear in the furnace spectrum.

At a later stage, the neutral-atom lines disappear, those of the easily-ionised atoms first, the more refractory later. Thus the spark spectrum (lower-temperature) has faint neutral lines and strong enhanced or ionised lines, because ionised atoms now preponderate; faint lines of the atoms most easily doubly-ionised will also begin to appear in the lower-temperature spark spectrum.

At still higher temperatures, the ionised lines also disappear, being gradually replaced by the lines of doubly and trebly ionised atoms, and finally, at the highest obtainable spark temperature, and the still higher temperature of the O stars, hardly any lines are left in the visible spectrum except those of hydrogen and ionised helium—the latter of which has a very high ionisation potential. Lines of the other elements, however, exist, but mostly in unobservable positions in the ultra-violet.

* Somewhat different meaning from the ordinary volt.

† Large capitals are also used, but the small capitals are much clearer.

IV. NOTES ON THE SUN, PLANETS, STARS, &c.

The Sun, as an object for small telescopes, is of little interest unless sunspots are visible: special precautions are required in observing it so as not to injure the eyesight (see p. 34).

The disc of the Sun visible on ordinary occasions, known as the *photosphere*, presents a granular or 'rice-grain' appearance in large telescopes. Even in a small instrument of 2 or 3 inches aperture, the surface will show a mottled appearance, when the air is steady and definition good; but this mottling is of a coarser texture than that delicate granular appearance seen under higher powers with large instruments. *Faculae*, i.e., irregular, more or less streaky patches, somewhat brighter than the average surface, may generally be seen. They are elevations above the general level of the photosphere, and exist on every part of the disc, but are most numerous in the neighbourhood of sunspots. They are best seen near the limb or edge of the disc, since the photosphere in this region is perceptibly darker than at the centre of the disc, having only some 37 per cent of the brilliancy, according to Pickering. This is due to the absorption by the Sun's atmosphere of the light coming from within, which has to traverse a much greater depth of atmosphere at the limb, before reaching the Earth, than that coming from the centre: it therefore appears darker to us, contrasted with the faculae, which have not lost so much light owing to their greater elevation. The darkening is specially noticeable in solar photographs.

The Sun's Rotation may be traced by the daily motion of the spots across the disc from east to west, the 'synodic' apparent rotation period, as seen from the Earth, averaging $27\frac{1}{4}$ days: spots may thus be visible for about a fortnight at a time. The sidereal or true rotation period is about 25 days near the Equator, and 27 days at 35° ; the synodic rotation period, at these latitudes, varies in about the same proportion. The mean sidereal rotation period at present used in the *N.A.* and *A.E.* is 25.38 days (27.2753d. synodic), but a 25.2-day sidereal period, 27.1 synodic, is perhaps nearer the true value, being that favoured in the recurrence of sunspots, faculae, flocculi, prominences, and magnetic storms. The Sun's axis of rotation is inclined $7\frac{1}{4}^\circ$ from the vertical to the Ecliptic plane (see p. 34).

Carrington's Series of Rotations (25.38 day), used for statistics, has as zero meridian the Sun's prime meridian that passed through the ascending node at 0h., G.C.T., Jan. 1, 1854; No. 1 began Nov. 9, 1853; No. 1040, June 14.01, 1930 (0h. 36m.).

Sunspots vary in size from small 'pores,' as the smallest are termed, to groups so large as to be visible to the naked eye, on occasion. A sunspot presents the appearance of a dark irregular spot, or *umbra*, surrounded by a less dark portion, or *penumbra*; the *umbra*, however, is only apparently dark by comparison with its surroundings, being actually brighter than the electric arc, though its darkest portion, the *nucleus*, has only about 1 per cent of the brightness of the average surface: very black, round spots, known as *nucleoli*, are often seen in the umbra. *Bridges* from the photosphere, often intensely bright, may frequently be seen gradually encroaching on and dividing up the penumbra and umbra; in large spots, these can easily be seen with a 3-inch telescope, or even less. The size of spots varies from about 500 miles to some 50,000 miles in diameter. Those over 15,000 miles are *Naked-eye Spots*, visible without a telescope, when the Sun's brightness is sufficiently reduced by cloud, mist, or dark glass. The diameter of the spot, including the penumbra, may usually be roughly reckoned as being three times the diameter of the umbra. On rare occasions, a spot is visible as a small notch on the Sun's edge when just coming into or going out of view.

Sunspots are never seen at the Sun's poles, and rarely within 5° of the equator. They occur mainly in two zones between 10° and 30° of N. and S. solar latitude. Spots in 45° - 50° are rare, and no spot has yet been recorded beyond 60° . Sunspots have magnetic fields, and the polarity, + or -, of the 'preceding' or foremost spots of a group is opposite in the N. and S. hemispheres—which hemispheres may differ very considerably in their spottedness.

The Sunspot Period.—The spottedness waxes and wanes, a maximum being reached about every 11.1 to 11.15 years, on the average, but there is no definite period, intervals between maxima having varied from $7\frac{1}{2}$ to $16\frac{1}{2}$ years; the apparent 11-year cycle, however, is really a half-cycle, for the spot-polarity changes after every minimum.

The rise to maximum is usually more rapid than the fall, taking about $4\frac{1}{2}$ years; minimum spottedness is reached about $6\frac{1}{2}$ years later, when no spot may be visible for weeks. Large spots may appear at any part of the cycle.

Spoerer's Law states that the two spot-zones simultaneously move slowly from high N. and S. latitudes towards the equator. Nearing minimum—the end of each half-cycle—the spot-zones are near the equator; the new half-cycle begins when spots of opposite polarity break out in high latitudes, some time before the actual minimum is reached, and two or three years elapse before old-zone spots finally disappear. The new spot-zones gradually decrease in latitude, till, at the end of eleven years, they, in their turn, arrive near the equator; high-latitude spots of opposite polarity then appear, heralding the beginning of the second half of the cycle.

The variation of latitude is shown in a striking manner by plotting the spots of a cycle according to date and latitude. From its shape, this is known as a *Butterfly Diagram*.

* Spots not on the centre are, of course, greatly foreshortened when near the limb.

Sunspots and Magnetic Storms.—The curves of sunspot activity, of terrestrial magnetic storms, and (on the whole) of auroræ, closely coincide, indicating some intimate connection not yet wholly explained. A large spot near the centre of the disc often coincides with a magnetic storm, but not always, and on the other hand the return of a certain area to the centre of the disc sometimes causes a magnetic storm, though no spot is visible.

Wolf's Sunspot Numbers give the relative 'sunspot activity' for any year, based on the number both of groups and of individual spots—the size of telescope used, and the observer, being taken into account. The numbers vary from 0 to about 150 at the highest maximum, and they have been calculated back to 1610 (See *Memoirs R.A.S.*, vol.43). A sunspot number of 100 is equivalent to a sunspot area of about 1/500th of the visible disc.

Prominences or *protuberances* are jets or clouds of glowing red gas which rise all round the Sun's 'limb' or edge from the *chromosphere*, a bright scarlet, irregular ring of light, some 5" to 15" in depth at different times, seen only during total eclipses, or by means of a spectroscope attached to the telescope (see p. 34). *The reversing layer* is a thin stratum of gas which is responsible for the dark lines in the solar spectrum, absorbing certain portions of the bright light from the layers beneath, and reversing them into dark lines. In solar eclipses, just before the Sun disappears, it shows the lines bright instead of dark—a phenomenon known as the *flash spectrum*.

Filaments are long dark prominences seen in projection on the Sun's disc. *Motion-forms* are apparent filaments over a sun-spot, but in reality only distortions of the hydrogen (C) line caused by high radial motion.

Flocculi, seen or photographed by the spectro-heliograph, in one particular wave-length of light (usually that of calcium, sometimes hydrogen), are small irregular clouds of either of these elements, which are seen all over the disc, and show the distribution of the element over it. There are both bright and dark flocculi: the latter may take the form of long dark wisps. The *Solar Reseau*, or *Reseau Photospherique*, is an as yet unexplained blurring or fuzziness of the solar granulation; it is not known whether it is of solar or terrestrial origin. ('Reseau' also means the network of squares ruled on celestial photographs for measuring purposes).

The Corona, also seen only during total eclipses, is a mysterious, irregular, pearly ring of light surrounding the Sun. It is never quite the same, either in shape or extent, in successive eclipses, and appears to be partly gaseous, and partly meteoric, for it shines partly by reflected sunlight. It varies with the 11-year period of the Sun's activity, being more or less regularly distributed round the Sun at sun-spot maximum, while at sun-spot minimum there are large streamers, several degrees long, near the Sun's equator, with tufts or plumes of light near his poles. Its brightness varies, being at times uncomfortably bright, nearest the Sun, without a dark glass, especially when the Sun's and Moon's diameters are nearly the same, but on the average seems rather less bright than the Full Moon. The Corona spectrum has a characteristic green line ($\lambda 5304$) due to oxygen, once ascribed to an unknown element 'coronium'.

Baily's Beads are sometimes seen for an instant before totality—a breaking-up of the thin disappearing crescent of the Sun into a series of bright moving points, like a string of shining beads. Then, as totality begins, the prominences and corona appear until the Sun begins to emerge again; sometimes, however, they appear just before totality.

Shadow Bands or *fringes*, another eclipse phenomenon, are alternate light and dark bands, a few inches broad and 1 to 3 feet apart, that appear on white surfaces for an instant as totality begins: probably due to irregular refraction.

The Sun's Magnetic Poles are about 6° away (but perhaps this varies) from his rotation poles; they rotate in 31.29 days (31d. 7h.), and were on the Sun's central meridian on 25th June 1914.

The Sun's Temperature, that of a dwarf G0 star, is about 6000°K . ($10,000^\circ\text{F}$.) near the surface. The *Solar Constant*, the amount of heat received by the Earth (on entering the atmosphere) from the vertical Sun, is 1.93 gram-calories per minute on each square centimetre; variations of one to five per cent seem to occur from day to day. The temperature of sunspots is about 4800°K .— 1000°C . (1800°F .) less than that of the general surface.

Solar Motion.—The *Solar Apex*, or *Apex of the Sun's Way*, is the point on the star sphere towards which the Sun is travelling with a velocity believed to be about 19.5 kilometres (12.1 miles) per second. The position of the Apex is ascertained from study of proper motions, or radial velocities, but determinations differ, often by many degrees, different sets of stars giving varying results. In the main, however, there is agreement as to the general direction of the Apex being in Hercules or Lyra, about R.A., 18 hrs., Dec. 34°N . (or, as usually stated in degrees, R.A., 270° , Dec. 34°N .). The *Solar Antapex* is the point diametrically opposite on the star sphere, R.A. 6 hrs., Dec. 34°S .

Mean Daily Spotted Area of the Sun in millionths of the visible hemisphere (projected area, corrected for foreshortening).
 Year.— 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933
 Area. ... 7 152 697 724 1537 1118 1052 618 420 252 55 276 830 1262 1058 1390 1242
 Mean Lat. $23\frac{1}{4}^\circ$ $21\frac{3}{4}^\circ$ $18\frac{3}{4}^\circ$ $15\frac{3}{4}^\circ$ $14\frac{3}{4}^\circ$ $12\frac{3}{4}^\circ$ $10\frac{3}{4}^\circ$ $10\frac{1}{2}^\circ$ 8° 8° $15\frac{1}{4}^\circ$ $22\frac{3}{4}^\circ$ $20\frac{1}{4}^\circ$ $18\frac{3}{4}^\circ$ 15° $13\frac{1}{2}^\circ$ $10\frac{1}{2}^\circ$

Sunspot Maximum and Minimum (approximate). The polarity is that of the 'preceding' spots.)

Minimum	1901	1912-13	1923	...	...	...
Maximum	1905	1917-18	1927-28	...	...	...
Polarity.	N. -, S. +	N. +, S. -	N. -, S. +	N., S.	N. S.	N. S.

THE PLANETS.

The *Nautical Almanac* (N.A.), and The *American Ephemeris* (A.E.), give much useful planetary observing information. Under 'Phenomena' are given the dates of opposition, conjunction with the Sun and Moon, elongations of Mercury and Venus, &c.; there are Occultation Tables, with latitude-limits of observability, and those seen at certain stations; also Sunrise, Sunset, Moonrise, Moonset, and Twilight Duration Tables, for latitudes 0° to 60° . The 'Physical Ephemeris', &c., Tables give the position angle of the axis, planetary meridian on the centre of the disc, configuration and eclipses of the satellites, &c.; also:—

Mars and Jupiter. The angular amount of phase, (always on the W. side from conjunction to opposition, and on E. side from opposition until conjunction) is given by column *g*; the linear (=areal) fraction of the disc illuminated, by column *k*.

Column D $\oplus$ gives the number of degrees the planet's N. pole (+), or S. pole (−), is turned towards the Earth: maximum about $25\frac{1}{2}^{\circ}$ for Mars; 4° for Jupiter; 29° for Saturn; but largely nullified by foreshortening. 0° = both poles on limb.

Jupiter's Satellites. Configuration†: $\bigcirc$ at the side indicates 'In transit'; $\bullet$ 'In occultation or eclipse.' The Phase diagrams show for each satellite by a *, the position during the month (change slight, except near opposition) of the points where the satellites disappear in, or emerge from the shadow; *c* (or *d*), is the point of disappearance; *f* (or *r*), that of reappearance.

Saturn's Rings. Column B gives the angular 'openness' of the rings, 0° when invisible, about 28° fully open. Column B is Sun's elevation above the ring-plane; rings invisible when B or B' = 0° ; also when Earth is + (N) and Sun − (S), or *vice versa*.

The Calendar.—The student is recommended to study the very interesting and clearly-expressed article on this subject, and on astronomical terms, in the Appendix to the *British Nautical Almanac* for 1931, &c. The same volume contains an elaborate *precis* of the formulæ used in preparing the Tables in the Almanac, which will be useful to the advanced.

Heliocentric longitudes and latitudes, and radius vectors, giving orbital positions and distances with reference to the Sun, are given annually in the *American Ephemeris*, but in the *British N.A.* for Mercury only, those for the other planets having been published in advance, for every year up till 1940, in the *N.A.s* for 1915-17. The Earth's heliocentric longitude is the Sun's longitude + 180° . The perihelion longitude of each major planet increases some 2° per century.

A planet's elongation from the Sun is (roughly, when over 15° from Sun), the difference between their R.As. The hour of R.A. on the meridian at mean midnight is given for each day, 'Sidereal Time'; from this, that at other hours can be found.

General Notes.—The *Major Planets*, so called to distinguish them from the *Asteroids* or *Minor Planets*, none of which exceeds a few hundred miles in diameter, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto. The first four (with which Pluto may be reckoned) are sometimes distinguished as the *Terrestrial Planets*, as their sizes are comparable with that of the Earth, the others as the *Giant Planets*. Pluto excepted, they are always near the Ecliptic, within the limits of the ancient Zodiac (p. 3), and are readily distinguished from fixed stars, as they do not twinkle unless very low down. As their positions are constantly changing, they cannot be inserted in the star charts, but their places among the stars are easily found by the R.A. and Declination given in almanacs.

Unlike the Moon, which souths about 50 minutes later each evening on the average, the *Superior Planets* (Mars, the asteroids, Jupiter, Saturn, Uranus, Neptune, Pluto) south earlier each night, appearing to move nearer the Sun when east of him, but further away when west of him, and being lost in his rays for some six weeks.

The Superior planets are best seen when in opposition, southing about midnight; the *Inferior planets* (Mercury, Venus), about the times of greatest elongation. Opposition or greatest elongation may occur at any time of the year, but the nearer they happen to one date in a certain month (Superior planets, that on which the Earth's heliocentric longitude is about the same as that of the planet's perihelion) the larger and brighter is the planet: years, however, elapse before the favourable conditions recur—very many years for the best. Variation in magnitude, see p. 13.

Uranus and Neptune are so distant that their maximum and minimum brightness only differ by about 0.5 and 0.2 magnitude respectively: the angular diameter also varies very little. But Pluto's very eccentric orbit causes his magnitude to vary from about mag. $12\frac{3}{4}$ to 15; when discovered, he was about mag. 14 to $14\frac{1}{2}$ (photographic, 15 to $15\frac{1}{2}$).

The angular diameters and masses of the planets, also *Bode's Law* of planetary distances, are given on page 18. The spectra of the four Giant planets are those of reflected sunlight, with some bands of unknown origin, which are strongest in Uranus and Neptune, suggesting some low-temperature agency.

The Solar System.—Most of the figures below are from, or based on, those of the *American Ephemeris*, to which refer if greater precision is wanted. Where two diameters are given, the smaller is the polar, and the larger the equatorial. Mean Distance from Earth:—Inferior planets, = unity: Superior planets, = mean dist. from Sun; mean opposition distance, 1 unit less.

Diameter: Sun, 864,000 miles, 1,287,500 km.; Moon, 2160 miles, 3476 km. **Density:** (water = 1) Sun, 1.42; Moon, 3.34.

Angular Diameter: Sun, mean $31' 59''$, (max. $32' 36''$, min. $31' 31''$, approx.); Moon, mean $31' 5''$, (max. $33' 31''$, min. $29' 22''$).

Planet and Symbol.	Mean Distance fr. Sun.			Diam. Miles	Density		Period.			Orbit: Epoch 1920.					
	Astron. Units	Millions of Miles	Kilom.		Water =1	Sun =1	Sidereal, in years	Synodic, in years	Axial Rotation	Eccen- tricity	Inclin. to Eclipt.	Longit. perihelion	Longit. Asc. node	Motion	
Mercury ♀	0.387	36.0	57.9	3,000	3.7	2.6	0.2408	0.3173	88 ^d ?	0.2056	7.00°	76.2°	47.4°	4.09°	...
Venus ♀	0.723	67.2	108.1	7,570	5.2	3.7	0.6152	1.5987	225 ^d ? 68 ^h ?	0.0068	3.39	130.4	76.0	1.60	...
Earth $\oplus$	1.000	92.9	149.5	7,927 7,900	5.5	3.9	1.00004	...	23 ^h 56 ^m 4 ^s	0.0167	...	101.6	...	0.99	360°
Mars ♂	1.524	141.5	227.8	4,200	3.9	2.7	1.8809	2.1354	24 ^h 37 ^m 23 ^s	0.0933	1.85	334.6	48.9	0.52	191 $\frac{1}{2}$
Jupiter ♃	5.203	483.3	777.8	88,700 82,800	1.3	0.9	11.8622	1.0921	9 ^h 50.55 ^m	0.0484	1.31	13.0	99.6	0.08	30 $\frac{1}{2}$
Saturn ♄	9.539	886.1	1426	75,100 67,200	0.7	0.5	29.4577	1.0352	10 ^h 14 ^m 24 ^s	0.0558	2.49	91.5	113.0	0.03	12 $\frac{1}{2}$
Uranus ♅	19.19	1783	2869	30,900	1.4	0.9	84.0153	1.0121	about 10 $\frac{3}{4}$ ^h	0.0471	0.77	169.4	73.6	0.01	4 $\frac{1}{2}$
Neptune ♆	30.07	2793	4496	32,900	1.3	0.9	164.788	1.0061	15 ^h 48 ^m	0.0086	1.78	43.9	130.9	0.006	2 $\frac{1}{2}$
Pluto ♇	39.52	3678	5920	4000?	...	...	248.430	1.0047	...	0.2486	17.14°	212.5°	108.2°	0.005°	1 $\frac{1}{2}$

† The direction of motion is towards the figures.

Mercury is always so close to the Sun, that, even when most favourably situated, it is only observable for about 2 hours (to the naked eye, $\frac{1}{2}$ hr.), after sunset or before sunrise, and at a very low altitude, especially in higher latitudes. The great ellipticity of the planet's orbit causes the extent of its greatest elongation to vary considerably, between the limits of 16° and 29° , and it is best seen when greatest elongation is near the time of the equinoxes; it is then better situated for those in the S. hemisphere, as the maximum greatest elongation (29°) is attained at aphelion, when S. of the celestial equator. In European latitudes it is most favourably placed in the spring, as an evening star, some days before greatest east elongation, one in April being best; or as a morning star, some days *after* (maximum) west elongation. Observers in the tropics have the best conditions, the planet being higher above the horizon than in temperate latitudes. Mercury has phases like the Moon. Average elongation magnitude, $+0.2$; maximum, near superior conjunction in perihelion, -1.8 : angular diameter, $4\frac{1}{2}''$ to $14''$. The synodic period is about 116 days: sidereal period, 88 days.

The interval between greatest E. and greatest W. elongation is about 44 days, inferior conjunction being between, while from greatest W. to greatest E., with inferior conjunction between is about 72 days. Rotation period, 88 days.

Venus, the brightest of the planets, can sometimes be seen in broad daylight. Its dazzling brightness renders observations of the surface-markings very difficult, and for small telescopes its chief interest is that it has phases like the Moon—sometimes discernible even with an opera-glass: examine in the daylight, or as soon as possible after sunset or before sunrise. It appears brightest during the 'crescent' phase—as an evening star about a month *after*, and as a morning star about a month *before* its greatest elongation (maximum 47°). The maximum brilliancy is not attained when the planet is closest to the Earth—which occurs when inferior conjunction takes place about the end of December, and the planet is quite invisible—but when it is in perihelion, about the same date, as a morning star. At this time it is not only in the most favourable phase-situation for brilliancy, but it is also most brightly lit up by the Sun. It is slightly less bright when seen in perihelion about the middle of March as an evening star, as in 1921, but is much higher above the horizon in the northern hemisphere than at the December perihelion, which is most favourable for those in the southern hemisphere.

The maximum magnitude, which occurs about every 8 years, is -4.4 , when Venus is about 12 times brighter than *Sirius*. The angular diameter of the disc of Venus varies from $10''$ to $65''$. The synodic period is about a year and seven months (584 days), and in consequence of this slow motion, it remains visible for several months at a time, unlike Mercury, which rapidly disappears in the Sun's rays. The interval between greatest E. and greatest W. elongation is about 144 days, inferior conjunction being between, while from greatest W. to greatest E., with superior conjunction between, is about 440 days. The Sidereal period is 224.7 days ($\cdot 6152$ year). Rotation period uncertain: a 23-24 hour period was generally thought probable, till Schiaparelli and Lowell declared it to be the same as the sidereal period: more recently, Pickering finds it to be 68 hours, with the rotation axis inclined only 5° to the plane of the orbit.

A curious luminosity on the dark side of the crescent planet—similar in appearance to Earthshine on the Moon, but as yet unexplained—is occasionally visible. Spots also are sometimes seen, but it is doubtful if these are permanent features. Daylight observation diminishes the glare of the planet.

Recurrence of Favourable Elongation at the same time of day, in the case of Mercury, takes place about every six years about April (evening) and August (morning); in the case of Venus about every 8 years.

Mars is of little interest in a small telescope, except when at or near opposition. Favourable oppositions occur about every 15 or 17 years (from 1924). When furthest from the Earth the diameter is only $3\frac{1}{2}''$. His diameter at opposition, when he is nearest the Earth, or from 35 to 62 million miles distant, varies from $13''$ to $25''$. On the ruddy disc of the planet, dark greyish-green markings, formerly thought to be seas, but now supposed to be marshes or vegetation areas, can be seen.* The finer straight markings, the so-called 'canals,' are invisible in very small telescopes. One or other of the bright, white polar spots (probably snow caps) is generally a striking feature: occasionally both are visible. It is 'gibbous,' i.e., not fully illuminated, except near opposition; the greatest gibbosity is at quadrature.

Nearly two years and two months elapse between successive oppositions of Mars, the mean synodic period being 780 days—the longest of any of the planets. The most favourable oppositions occur about August 26, when Mars rivals Jupiter in brightness, his magnitude being -2.7 , though his disc has only half the angular diameter, so that small instruments cannot show much detail. The mean and minimum opposition magnitudes are about -2.25 and -1.0 . When farthest from us, for some time before and after conjunction, Mars is only about magnitude 2. The rotation period is 24 h. 37.4 m., and the sidereal period 1.88 years. (See note on *N.A. Tables*, p. 24).

* For Charts of the markings and nomenclature of Mars, see Webb's *Celestial Objects*, and the Brit. Astr. Assoc. Reports on Mars.

Jupiter is a fine object for small telescopes, his elliptical disc, darker at the edges than in the centre, and 'parallel belt' markings being plainly seen: he is very slightly gibbous when in quadrature. The markings indicate a rotation period of 9 h. 50.5 m. near the equator, and a slower rotation of 9 h. 55.7 m. in the temperate zones. Two systems of defining the positions of markings are based on these periods, and the times of transit of the zero meridians across the centre of the disc, are given in the *Nautical Almanac*, also the configuration, eclipses, and occultations of the satellites. For reference, the disc is divided into equatorial, tropical, and temperate 'zones,'—which are crossed by seven darker 'belts': the narrow 'Equatorial band,' the Equatorial (N. & S.), and Temperate (N, NN; S, SS) belts—and the N. & S. Polar regions

The 'Great Red Spot,' prominent as such in 1878, was about 13" by 3" (30,000 × 7000 miles), and its rotation period has varied by several seconds. Bright red till 1881, by 1892 it had faded to a pale orange, and has since shewn little colour. In 1919 and 1920 remarkable and rapid changes occurred in this region, the Spot disappearing altogether, and reappearing again. For details of recent changes see the British Astron. Association 'Memoirs' and 'Journal.'

Year after year, oppositions take place a month later in the season, the synodic period being 399 days. Favourable oppositions take place at intervals of about 12 years, the most favourable being those nearest September (1916, 1927, &c.), when Jupiter's magnitude is about -2.6 ; the mean opposition magnitude is about -2.30 , and the minimum magnitude about -1.1 . The angular diameter is 30" to 50"; and the sidereal period, 11.86 years.

Four of Jupiter's satellites, or 'moons,' are visible in an opera-glass, all being about magnitude 6; the others only in giant telescopes. Three of these satellites are eclipsed by Jupiter's shadow once every revolution, but they do not disappear instantaneously, as the motion is slow. Sometimes a satellite 'transits' or passes across the face of the planet, appearing, at the beginning or end of the transit, as a bright spot on a dark background (the limb, or edge, of the planet's disc being darker than the centre), while at intermediate times it may disappear from view altogether, if the background happens to be similar in brightness and colour, or it may appear as a dark spot. The shadows of the satellites also transit the planet's disc, showing as dark spots, which are apt to be mistaken for the satellites themselves; sometimes both satellite and shadow may be seen transiting at the same time. Occultations, which occur when the satellites pass behind the body of Jupiter, are frequent, but generally of little interest, though, when Jupiter is in quadrature, phase effect (p. 6) may make the satellite disappear, or reappear, away from the planet's apparent limb (phase is on the W. side before opposition; on the E. side, after). The chief satellites are numbered consecutively I, II, III, IV—I being nearest the planet.

Saturn is also a magnificent object for a small telescope. The disc is very slightly darker at the edges than in the centre, and he is even more elliptical in shape than Jupiter, but this is only seen fully when the Earth is in the plane of the rings. Faint parallel-belt markings may be discerned, but his special feature is the wonderful 'ring' system, divided into two by a hair-like dark line known as 'Cassini's Division,' just visible in a 2½ in. refractor when the rings are widely open. A dusky ring, nearest the planet, called the 'Crape or Gauze Ring,' can be seen in a 4-in. telescope. The portions of the rings which project beyond the planet's body are known as the *ansa*, the one in the direction in which the planet is moving in the telescope being termed the 'preceding' *ansa*; the other, the 'following' one. The rings are designated A, B, and C; the outermost, A, is fainter than B, and both have been seen to be sub-divided in powerful telescopes; C is the dusky Crape Ring. For 'openness' of the rings, satellite configurations, &c, see *N.A.**

Twice during Saturn's sidereal circuit, at intervals of 15½ and 13½ years (from Aug. 1921), when he is in the signs of Virgo or Pisces, *i.e.*, when his longitude is 168° or 348°, the rings present their edge to the Sun or to the Earth, or else turn their unilluminated side towards us, and in each case become almost or quite invisible for a short time. When their thin edge (considered by Bond to be only 40 miles thick) is turned towards us, the ring is possibly for a few hours beyond the reach of our best telescopes. About 7-8 years later, when the planet is in the signs of Gemini or Sagittarius, *i.e.*, in longitude 258° and 78°, the rings are fully open, and he is about twice as bright as when they are invisible.

Favourable oppositions of Saturn occur about every 29 years (from 1914), the most favourable being those about the middle of December. As the synodic period is 378 days, and year by year, oppositions recur only about a fortnight later in the season, there will be a succession of comparatively favourable oppositions when they happen about that date. The mean opposition magnitude is given as about -0.93 , but owing to the varying apparent width of the rings, the brightness of Saturn does not follow the same simple law as the other planets: ringless, estimates of its magnitude vary from 0.65 to 0.87. Angular diameter, 15" to 20": rotation period about 10½ hrs., but measurements vary; Herschel I. gives it as 10h. 16m.; Hall (1876), 10h. 14m. 24s.; Denning (1903), 10h. 37m. 56s. Sidereal period 29.46 years.

Saturn's brightest satellite, Titan (mag. 8.3) may be seen with a very small telescope; Rhea, Tethys, Dione, and Iapetus (mags. 10.0, 10.6, 10.7, 10.9, respectively) with a 4 in. instrument, the first sometimes with a 3 in., or even less.

* Refer to *N.A.* Note on page 24.

Uranus appears as a star of the 6th magnitude to the naked eye. Its disc, having an angular diameter of only $3\frac{1}{2}''$, and also its satellites, are distinguishable only in large telescopes. Owing to its great distance, there is practically no change in its brightness at different times. Synodic period about 370 days, and sidereal period 84.02 years.

Neptune can be seen with the aid of an opera-glass when its position is found by reference to an almanac and the star charts, but is a faint and uninteresting telescopic object. Angular diameter, $2\frac{1}{2}''$; opposition magnitude, 7.8, which, as in the case of Uranus, is practically unchanging. Synodic period $367\frac{1}{2}$ days, and sidereal period 164.79 years.

The Asteroids, or Minor Planets, are all invisible to the naked eye except Vesta (oppos. magnitude $6\frac{1}{2}$), being very minute. The most interesting is Eros, one of the smallest; its orbit is so eccentric that at times it approaches nearer to the Earth than any other planet—within 14 million miles, about half the least distance of Venus—and at favourable oppositions (as in 1931) affords much the most accurate means of ascertaining the Sun's true distance from the Earth. At these times it attains about magnitude 7, but it is usually beyond the range of small telescopes.

The *Trojan* or *Jupiter Group* of planets, several asteroids named after heroes in the Trojan war, are noteworthy in having orbits very near to that of Jupiter, and revolving approximately equidistant from the Sun and Jupiter.

In addition to being named, asteroids are also numbered—symbolised thus ⑨—roughly in the order of their discovery, but only when the orbit has been determined; till then they are designated by Roman letters (see page 40). There are now some 1200 numbered asteroids. (New discoveries, and numbers, see Annual Report (Feb.) Royal Astr. Socy.).

Pluto, discovered 1930, has a very eccentric orbit, highly inclined (17°) to the Ecliptic; at perihelion, in 1989, he comes nearer the Sun than Neptune. The magnitude varies from about mag. $12\frac{3}{4}$ to 15. For period, &c., see p. 24.

Double Stars are stars which to the naked eye appear as a single point of light, but when viewed through a telescope are found to be composed of two stars—not necessarily physically connected, as they may simply happen to be in the same line of sight. *Triple Stars* have three, *quadruple stars* four, and *multiple stars* many components. Where one of the stars is of a much smaller magnitude than the other, it is often styled a *comes* (plural *comites*) or companion. The most interesting 'doubles,' &c., are indicated in the Notes appended to each star chart.

Binary Stars are double stars which are 'physically connected,' revolving round a common centre of gravity, and not merely chancing to be in the same line of sight. *Spectroscopic Binaries* are those found to be binary by the temporary doubling and displacement of the lines in their spectra, although too close together to be 'resolved,' i.e., seen separate in the telescope. Visible binary stars have periods varying from a few years to many centuries. If the plane of their orbit is in the line of sight from the Earth, they may be seen to approach closer and closer together, and at last appear to the eye as a single point for a considerable period, afterwards opening out again.

In a binary system, the motion of the companion is *direct* when the position angle is increasing in degrees, and *retrograde* when decreasing. The smaller star is sometimes said to be in *periastron* with the principal star, when actually (as distinct from apparently) nearest to it; and in *apoastron* when furthest from it.

Star Clusters are small groups of stars, crowded more or less closely together, which in the telescope are glorious sights (see Notes, Star Charts). *Star Clouds* differ in being portions of the Milky Way itself in which the stars are so closely packed as to appear as a continuous irregular bright cloud: they are most conspicuous in Sagittarius, in which the centre of the Galactic System seems to be situated. Star clusters, proper, are of two kinds:—

Globular Clusters are globe-shaped, densely-packed masses of stars, thinning out rapidly at the edges of the central condensation, then slowly when the distances between individual stars has become considerable; M 13 in Hercules (N.G.C. 6205) is a typical specimen. Over 100 are known,* few nearer the Galactic Plane than about 10° , and all lie in the region between 149° and 41° Galactic longitude, which indicates considerable eccentricity with respect to the Sun. They also occupy a place opposite to the majority of the *Spiral nebulae*, being mostly in Ophiuchus and Sagittarius.

Open Clusters have no central condensation, are more or less irregular in form, are often associated with nebulosity, and are most numerous opposite the region in which the Globular clusters predominate. The *Præsepe* in Cancer exemplifies one type, somewhat resembling an open Globular cluster; the *Pleiades*, in Taurus, represents another type, an irregular, yet well marked group, the components of which have a common motion.

Moving Clusters or *Star Groups* are not clusters in the ordinary sense, but groups of stars which have evidently some intimate relationship, as they are moving with similar velocities towards the same point on the star sphere. Proctor termed this phenomenon 'star-drift.' The individual stars may be in widely different parts of the star sphere. The best known are the Taurus, Perseus, and Ursa Major groups: the latter includes β , γ , δ , ϵ , ζ , of Ursa Major, and the apparently unconnected stars δ Leonis, Sirius, β Eridani, β Aurigæ, and α Coronæ Borealis.

The Local Cluster, inferred to exist from the study of parallaxes, magnitudes, &c., is believed to be a bun-shaped aggregation of stars, like a very open Globular cluster, to which our Sun appears to belong, and in which he is situated a little to the north of its central plane, and some distance to one side of its centre. Its central plane is inclined 10° - 15° to the plane of the Galaxy, and its stars are relatively near us, compared with the Milky Way, and comparatively close together, while its diameter is of the order of 1000 parsecs, or 3000 light-years. The majority of the brighter B stars seem to belong to this cluster, and according to Shapley its apparent centre is in Carina.

* See List in *H.A.*, Vol. 76, and *H.C.O.* 776.

The Milky Way or Galaxy extends right round the star sphere, forming a great ring which is inclined about 61° to the plane of the Ecliptic, and slit lengthways at one part. It is composed of millions of minute stars of magnitudes 10 to 12, on the average, Types A and K being most common, and has some 8500 stars per square degree in Cygnus, as compared with 178 for the Galactic Poles, and the 2500 average for the whole sky.

Between Cygnus and Scorpio the Galaxy forms two narrow parallel bands for some 110° , then is very much broken up and complex for a considerable distance, but brighter, especially in Sagittarius, where the individual stars in the 'star clouds' are so densely packed as to be indistinguishable; these are not well seen in Europe, however, as they south low down in mid-summer. In Argo, in the Canopus region (50° S.), the Milky Way is completely divided across for a short distance, but in Canis Major it again becomes a single, though fainter band, which narrows to about 5° in Taurus, and broadens out once more in Perseus and Cassiopeia; its very variable width is some 15° on the average, but in many places it is 20° or 30° , or more.

In the N. hemisphere it is brightest in Cygnus and Aquila; in the Southern, in Scorpio and Sagittarius; it is faintest in Monoceros. Photographs of the whole Milky Way are given in *Harvard Annals*, vols. 72 and 80; owing to the 'colour index' effect,* however, it is often difficult to identify star groups conspicuous to the naked eye, bright M stars being rather faint, and faint B or A stars conspicuous. This applies to all stellar photographs on ordinary plates.

The *Coal Sack*, a remarkable gap (starless to the naked eye) in the Milky Way, near the foot of Crux, appears like a dark abyss in the surrounding brightness; the darkness, however, is largely due to contrast, as, in a photograph, the area is much brighter than the non-galactic regions in the vicinity. This gap, and similar but smaller gaps in Cygnus and elsewhere, are believed to be due to Dark nebulae (p. 30) intervening between us and the Galaxy beyond, as is also the Great Rift in Argo, thought to be no further than 600 light-years from us.

Novae, Wolf-Rayet stars, Cepheid variables, Planetary nebulae, the Gaseous nebulae, stars of Types B and N, and eclipsing binaries, show a strange preference for the Milky Way and its neighbourhood, while the Globular clusters and White nebulae seem to avoid it; the reason for this distribution is not known.

The nearer portions of the Milky Way appear to be not more than 5000 parsecs, or 16,000 light-years distant; it is not yet certain whether its inner boundary is fairly definite, or whether the stars merely thin out after the manner of an open cluster; there is much reason for thinking that it is a Spiral nebula. How far the Galaxy extends on the side away from us we have no means of knowing; the consensus of opinion is that it is partly an optical effect due to the star concentration in that plane. The Sun is some distance to one side of its centre, which appears to be in Sagittarius, and he is a little to the N. of the Galactic plane, as the Galaxy is slightly less than a great circle on the star sphere—a 'small circle' of 88° (*Struve*). The Sun may be some 60,000 light-years from the Galactic centre.†

The Galactic Plane, passing through the central line or equator of the Milky Way (Galactic lat. 0°), is of fundamental importance in stellar study, owing to the peculiar distribution of various classes of objects with respect to it. This plane is completely defined by the position of its N. pole, but authorities differ somewhat as to its course: some determinations of the N. Galactic pole are given below; Newcomb's position includes the 'branch.' Argelander's is by some known as the 'Standard System.' The Galactic Charts (Maps 17 and 18) are based on Walkey's determination.

Authority.	R.A. = h. m.	Dec. N.	Authority.	R.A. = h. m.	Dec. N.	Authority.	R.A. = h. m.	Dec. N.
Herschel,	$187\frac{1}{4}^\circ$	(12 29) $31^\circ 30'$	Marth, (1872) ...	190°	(12 40) $30^\circ 0'$	Newcomb, (1904)	191°	(12 44) $26^\circ 48'$
Argelander,	190°	(12 40) $28^\circ 5'$	Gould (<i>U.A.</i> , 1875)	$190\frac{1}{4}^\circ$	(12 41) $27^\circ 21'$	Walkey, (1914)	$191\frac{3}{4}^\circ$	(12 47) $27^\circ 0'$

The N. Galactic pole is on the confines of Coma Berenices, where the White Nebulae cluster thickly; the southern one in Sculptor, about 10° S. of β Ceti. The Galactic plane (*U.A.*, 1875) is given below: the figures for $19h.$, $19\frac{1}{2}h.$, &c., are the same as for $7h.$, $7\frac{1}{2}h.$, and so on, but taking the Declination as N. instead of S.

R.A.	Dec.	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.	R.A.	Dec.
$7h$	$8^\circ 56' N$	$19h$	$9^\circ 47' 48' N$	$21h$	$11^\circ 60' 13' N$	$23h$	$13^\circ 62' 30' N$	$1h$	$15^\circ 57' 50' N$	$3h$	$17^\circ 39' 36' N$	$5h$	$17^\circ 30' 38' N$	$7h$	$18^\circ 19' 8' N$	$9h$	$18^\circ 5' 28' N$
$7\frac{1}{2}h$	$22^\circ 10' N$	$19\frac{1}{2}h$	$9\frac{1}{2}^\circ 52' 23' N$	$21\frac{1}{2}h$	$11\frac{1}{2}^\circ 61' 29' N$	$23\frac{1}{2}h$	$13\frac{1}{2}^\circ 62' 7' N$	$1\frac{1}{2}h$	$15\frac{1}{2}^\circ 55' 6' N$	$3\frac{1}{2}h$	$17\frac{1}{2}^\circ 30' 38' N$	$5\frac{1}{2}h$	$18^\circ 19' 8' N$	$7\frac{1}{2}h$	$18^\circ 5' 28' N$	$9\frac{1}{2}h$	$18^\circ 5' 28' N$
$8h$	$33^\circ 3' N$	$20h$	$10^\circ 55' 51' N$	$22h$	$12^\circ 62' 16' N$	$0h$	$14^\circ 61' 3' N$	$2h$	$16^\circ 51' 22' N$	$4h$	$18^\circ 19' 8' N$	$6h$	$18^\circ 5' 28' N$	$8h$	$18^\circ 5' 28' N$	$10h$	$18^\circ 5' 28' N$
$8\frac{1}{2}h$	$41^\circ 26' N$	$20\frac{1}{2}h$	$10\frac{1}{2}^\circ 58' 23' N$	$22\frac{1}{2}h$	$12\frac{1}{2}^\circ 62' 37' N$	$0\frac{1}{2}h$	$14\frac{1}{2}^\circ 59' 50' N$	$2\frac{1}{2}h$	$16\frac{1}{2}^\circ 46' 21' N$	$4\frac{1}{2}h$	$18\frac{1}{2}^\circ 18' 5' N$	$6\frac{1}{2}h$	$18\frac{1}{2}^\circ 5' 28' N$	$8\frac{1}{2}h$	$18\frac{1}{2}^\circ 5' 28' N$	$10\frac{1}{2}h$	$18\frac{1}{2}^\circ 5' 28' N$

The Magellanic Clouds or *Nubecula Major* (the Greater Cloud), and *Nubecula Minor* (the Lesser Cloud) are invisible from the latitude of Europe and the United States, their respective Declinations being 70° and 73° S., and their R.A.s $5h. 30m.$ and $0h. 50m.$ To the naked eye they appear like detached portions of the Milky Way, from which they are some 30° to 40° distant; in the telescope they are seen as a marvellous combination of stars, clusters, and nebulae. Distances of the order of 100,000 light-years; diameters 14,000 and 6,500 light-years, respectively.

The Stellar System.—Present evidence indicates that it is a lens-shaped disc, some ten or twenty times longer than its greatest thickness—the stars thin out rapidly towards the Galactic poles—and at least 300,000 light-years across, in its longer diameter. There is no evidence for a central sun, once confidently believed in. The vast distances of the Magellanic Clouds and the Spiral Nebulae indicate that they are separate universes, especially the latter; some of which, in Virgo, Canes Venatici, Ursa Major, and Leo, are at distances of from 10 to 105 million light-years or more.

* i.e., the differing visual and photographic magnitudes of many stars.

† Shapley.

Variable Stars are those which wax and wane in brightness; there are many varieties, which afford a useful and interesting study for amateur observers. The more important types are given below (See Note on Observing, p. 36).

When a variable star is, for the time-being, a morning star, rising shortly before sunrise, its maximum or minimum is called a 'morning' one. Similarly, 'spring,' 'autumn,' maxima, &c., refer to the time of year at which they occur.

- I. **Novæ**, or New stars, also called 'Temporary Stars,' suddenly blaze out where no star of that magnitude has been known before, but soon fade away to a small fraction of their maximum brightness; may be visual, telescopic, or photographic, and generally identifiable with some previously-known very faint star. Characteristic spectrum, with maximum intensity far in the ultra-violet—sometimes having broad, bright, and dark bands side by side, as yet unexplained—which soon changes, following, on the whole, but with individual peculiarities, the sequence detailed on page 39, and finally becoming identical with that of a Wolf-Rayet Star. (See List of Novæ below, and note on Nomenclature, p. 40).

It is probably significant that most Novæ yet discovered (except those in nebulae), are either in, or near, the Milky Way, and that they greatly preponderate in one direction, 14 Novæ (modern) having appeared from 0° to 90° Galactic longitude; 8 Novæ from 90° to 180°; 4 Novæ from 180° to 270°; and 16 Novæ from 270° to 360°. Novæ appear in Spiral nebulae, apparently of two types—one, like ordinary Novæ, of absolute mag. about -5, the other about -15.

- II. **Long-Period Variables.** *Mirids.* Periods, 90-600 days, averaging 300 days: red stars (Giants), of Types M or N, sometimes S, K, or R. Range of variation usually several magnitudes; periods and maximum magnitude attained, usually irregular; rise of magnitude usually much faster than the decrease. Typical star, α Ceti (*Mira*): see Notes on Map 4.

- III. **Irregular Variables.** Stars of all types from G to N, sometimes associated with nebular matter; no regular period; most vary only a magnitude or two. Many varieties, but five chief divisions:—

- Red stars with slight variations, like μ Cephei. [Tauri, R Scuti, W Cygni.]
- RV Tauri* Type. Variation averaging 2 magnitudes. Bright and faint maxima somewhat like the Lyrids. Typical stars, RV
- U Geminorum* Type. Constant minimum for many weeks or months, then a sudden blaze-up of several magnitudes in alternate long and short maxima, with slower fall to a constant minimum.
- R Coronæ Borealis* Type. Normal for months or years, then decreases many magnitudes, and after an irregular interval of similar order to the period of normality, returns to normal. Rises less quickly than it falls. See Notes, Maps 11-12.
- Nova-like Stars*; quick rises like the Novæ. Most notable star, η Argûs, see Notes on Maps 9 and 10.

- IV. **Short Period Variables**, with periods mostly less than 50 days—excluding those of 'eclipse' Type.

Cepheids. Giants with a rather sudden rise of light, followed by a more gradual fall to minimum; periods from a few hours to a month or two, but averaging 7 days; range of variation usually less than one magnitude; spectrum at minimum may be a whole Type lower than at maximum. Typical star, δ Cephei; see Notes, Maps 1 and 2. Cepheids are of great importance for finding stellar distances, as those of the same period have the same absolute magnitude.

Cluster-type Cepheids are those with less than 24-hr. periods, being found in great numbers in the globular clusters.

Pseudo-Cepheids are stars with spectra similar to those of Cepheid variables, but which do not vary in brightness.

- V. **Eclipsing Variables**, so called because the decrease in brightness is due to eclipse, at regular intervals, by a companion, which may be fainter or dark. The Lyrids are also classed as short-period variables, but are now believed to be eclipse-*Algolids*. A single well-marked minimum, sometimes a slight secondary one. Typical star, *Algol* (Notes Map 5). [type. (*Antalgol* type. A kind of Cepheid like S Aræ, with a light-curve opposite to that of Algolids; name now obsolete.)
- Lyrids.* Two equal maxima, with a small intervening minimum between them, followed by a large minimum: also called *ellipsoidal* on account of the shape of their components. Typical star, β Lyræ; see Notes on Maps 13 and 14.

- VI. **Secular Variables**—stars which, in the course of centuries, have imperceptibly faded or increased in brightness, of which there is some evidence. Thus the Greek legend of the fading away of *Sterope*, one of the Pleiades, is probably based on an astronomical fact. β Libræ, and *Castor* are other supposed examples.

Novæ before A.D. 1572.—Very doubtful ones omitted: those marked * probably comets. 'v. br.' = very bright.

B.C.	Nova:—	Mag.	Position.	A.D.	Nova:—	Mag.	Position.	A.D.	Nova:—	Mag.	Position.	A.D.	Nova:—	Mag.	Position.
134.	Scorpii*	1	near β	173.	Centauri	1	bet. α & β	393.	Scorpii	v. br.	in Tail	1012?	Arietis	v. br.	...
123.	Ophiuchi	1	" α	386.	Sagittarii, v. br.	"	" λ & ϕ	827.	"	1	"	1203.	Scorpii	1	in Tail
				389.	Aquilæ*	1	near α	1006.	"	-	"	1230.	Ophiuchi	1	nr. Serpens

Modern Novæ.—Only the brighter Novæ are included in the List.

Year A.D.	Nova:—	Greatest Mag.	Approx. Galac. Long.	Lat.	Position 1920. R.A.	Dec.	Year A.D.	Nova:—	Greatest Mag.	Approx. Galac. Long.	Lat.	Position 1920. R.A.	Dec.
1572.	Cassiopeia(B)	>1	87°	+1°	0h. 20 m.	63° 41' N.	1901.	Persei II	... -0.8	118°	-10°	3h. 26m	43° 31' N.
1600.	P Cygni I	3.5	43	+0	20 15	37 47 N.	1901.	Sagittarii IV	... 10	330	-3	18 2	27 26 s.
1604.	Ophiuchi I	>1	331	+7	17 27	21 25 s.	1903.	Geminorum I	... 5	152	+11	6 39	30 2 N.
1670.	Vulpeculæ(11)	3	30	0	19 44	27 7 N.	1905.	Aquila II	... 6.5	357	-5	18 58	4 34 s.
1848.	Ophiuchi II	4	335	+17	16 55	12 46 s.	1910.	Sagittarii II	... 7.5	330	-2	17 55	27 33 s.
1860.	Scorpii (T)	7	320	+20	16 12	22 47 s.	1910.	Lacertæ	... 5	70	-6	22 33	52 18 N.
1866.	Coronæ (T)	2	10	+47	15 56	26 10 N.	1912.	Geminorum II	... 3.3	151	+15	6 50	32 14 N.
1876.	Cygni (Q)	3	58	-8	21 39	42 28 N.	1913.	Sagittæ II	... 7.2	25	-8	20 4	17 27 N.
1885.	Andromedæ(S)	7	88	-23	0 38	40 50 N.	1917.	Scorpii II or } Ophiuchi V }	... 6.5	320	+9	16 50	29 30 s.
1887.	Persei I (V)	9.2	100	-5	1 56	56 21 N.	1918.	Aquilæ III	... -1.6	0	0	18 45	0 29 N.
1892.	Aurigæ (T)	4	144	-1	5 27	30 23 N.	1919.	Ophiuchi IV	... 7.5	6	+13	18 10	11 35 N.
1893.	Normæ	9	294	+4	15 24	50 28 s.	1919.	Lyræ	... 6.5	26	+12	18 50	29 7 N.
1895.	Carinæ (RS)	8	258	-1	11 4	61 30 s.	1920.	Cygni III	... 1.8	55	+12	19 56	53 24 N.
1895.	Centauri (Z)	7	284	+30	13 42	31 14 s.	1925.	Pictor RR	... 1.1	240	-25	6 35	62 34 s.
1898.	Sagittarii I	4.7	350	-8	18 57	13 16 s.							
1899.	Sagittarii III	8	334	-4	18 15	25 14 s.							
1899.	Aquilæ I	7	3	-7	19 16	0 17 s.							

Nebulæ are small, faint, misty, patches of light; only a very few are visible to the naked eye. They are usually more or less regular in form—spirals, spindles, ovals, and spheroids—but some are irregular or indefinite in outline; some are resolvable into patches of very faint stars; others are masses of incandescent gas of extreme tenuity, estimated as a thousand millionth of the density of air. There are various types:—

- I. **White or Non-galactic Nebulæ.** Appear about Galactic lat. 10° N. & S.; rapid increase to 30° , slower to 70° . Faint continuous spectra, more or less resembling that of a star; may be composed of myriads of faint stars; by far the most numerous type.

Spiral Nebulæ, mostly found by photography, are of this class, and are the most common; not found in the Milky Way, but tend to cluster about the Galactic Poles, especially the Northern one; thickest in the region opposite that in which the Globular clusters are most numerous. Distances of the order of millions of light-years; mostly receding from us at high velocities—300-15,000 km. (200-10,000 miles) per second—approximately proportional to their distance, about 500 km. (300 m.) per megaparsec. Some seen as 'spindles,' are obviously spirals viewed edge-on. The Great Andromeda Nebula (M31, N.G.C.224, visible to the naked eye), is of this type; distance 800,000 light-years, but approaching.
- II. **Gaseous or Galactic Nebulæ.** The first two classes of these tend to cluster in the plane of the Milky Way—unlike the White Nebulæ, chiefly found towards its north pole. There are several sub-divisions: (a) and (b) have bright-line spectra; but are believed to shine not by their own light, but by that of high-temperature stars within them.
 - a. *Irregular Nebulæ.* Preponderate towards the Milky Way; irregular or indefinite in form, distinguished telescopically by their greenish or bluish colour; small radial velocities. Chiefly composed of 'nebulium' ($\lambda\lambda 5007, 3727$), *i.e.*, ionised oxygen, OIII, OII, with hydrogen and helium; may be connected with earlier stages of star formation, often having stars shining in them, evidently intimately connected. Much fainter, and shown best by photography, are the nebulosities round, or joining, some stars (as in the Pleiades), also obviously connected with the stars. The Great Orion Nebula (M42, N.G.C.1976) is of this Type; distance may be about 1900 light years.
 - b. *Planetary Nebulæ.* More or less circular in form, and so-called because they much resemble the faint disc of a planet as seen in a telescope; only a few have a brighter central condensation. Tend to condense towards the Milky Way: related to Wolf-Rayet stars, which have similar spectra but smaller masses and velocities; also with Novæ, which towards the end of their outburst first become planetary nebulæ, then pass into their final stage, showing spectra identical with those of Wolf-Rayet stars. Mean velocity 25.3 km. (15.7 miles) per second: masses up to 150 times Sun's.
 - c. *Invisible Nebulæ*—unseen either by eye or camera—non-luminous clouds of calcium, hydrogen, and sodium, inferred to exist as the simplest means of accounting for stationary lines of these elements in the spectra of Novæ, and of some O and B binary stars of large mass; the star light, traversing the intervening nebula, suffers another absorption, and as the nebula is almost stationary, its absorption lines do not move to and fro as those of the moving components do.
- III. **Dark Nebulæ.** Supposed to cause the dark gaps in the Milky Way and elsewhere, and revealed by photography and star counts. Great irregular clouds of non-luminous opaque matter, most probably dust, which, being nearer to us than the Galaxy, shut out the light from the celestial objects beyond them. Largely in the neighbourhood of the Galaxy; believed to be no further away than 600 to 1000 light-years.

Twinkling of Stars. Though purely atmospheric in its origin, this phenomenon is of interest to astronomers, as it is affected by the nature of the light emitted by each star, *i.e.*, by its spectrum. White stars (Types B and A) twinkle most; yellow stars (Types F to K) slightly less, and red stars (Type M) least of all. Twinkling is least at the zenith, and in settled and calm weather; and greatest toward the horizon, and in unsettled and stormy weather: there is also a seasonal waxing and waning from mid-summer to mid-winter and *vice versa*. The reason why planets do not usually twinkle except when near the horizon, is supposed to be due to the fact that they have discs of an appreciable size.

The Green Flash, or 'Green Ray,' occasionally seen for a second or two before the instant of sunset or sunrise, is a beautiful solar phenomenon, due, like twinkling, to atmospheric causes; it is more often visible if an opera-glass is used. The general conditions required are a distant, sharply-defined, and low (preferably sea) horizon: avoid looking at the Sun till the last moment. Cool weather and absence of red tints seem to favour visibility. Sometimes it takes the form of a *white* flash followed by a deep blue one. A red flash is sometimes seen as the Sun's *lower* edge emerges from a dark cloud near the horizon: it may last minutes if the cloud's motion is nearly the same as the Sun's.

Auroræ are believed to originate in the Sun. There is general agreement between the sunspot maximum and minimum and their greatest and least frequency, and though no definite relationship with sunspots has yet been demonstrated, magnetic storms and auroræ frequently occur when large spots are on or near the Sun's central meridian: they may be due to rays shot out from certain areas of the Sun's surface, not necessarily radially, or from where a sunspot is seen. Auroræ appear in various forms: diffuse areas, arcs, rays, beams, curtains, patches, &c.; for details see p. 38.

Auroræ are most frequent about the time of the equinoxes—especially just after.* In Europe, some thirty may be seen annually on the line Inverness-Oslo; south of that line the number rapidly falls off, and south of the latitude of Paris, they only appear at long intervals. In America the corresponding limits are Quebec-Alaska, and Washington.

The colour of Auroræ is ordinarily faint white, silvery or delicate green in the brighter parts; red may appear, especially in the diffused type, or towards the lower edge of other types, and may pass into yellow-green. The ordinary height is some 87-300 kilometres (55-180 miles, but altitudes of 1000 km. (620m.) have been recorded. Phenomena, apparently auroral, also occur (rarely) near or even at ground level. The auroral spectrum has a characteristic green line— $\lambda 5577$, which also appears faintly in the spectrum of the night sky—due to oxygen and nitrogen.

* See 'Auroræ,' Encyclo. Britannica., 11th edition.

Meteors or Shooting Stars are of all degrees of brightness, from the faintest, lasting an instant, to the *bolide* or brilliant *fireball*, lasting several seconds: those that reach the Earth are called *aerolites*. Meteors may appear in any part of the sky, but there are certain well-marked points on the star sphere from which showers of meteors come every year at regular dates, when the Earth returns to the same part of its orbit. These showers are named from the constellation in which lies their *Radiant Point* or *Radiant*—so called because the meteors of the shower appear to radiate in all directions from that point in the sky. Many hundreds of radiants are known; the Table on p. 37 gives a few of the principal showers that may be looked for, and the approximate position of their Radiants. Those interested will find a long list in Webb's 'Celestial Objects.' In colour, the average meteor is more or less white, and is estimated to weigh not more than a single grain, from brightness and velocity considerations.

The meteors for any particular radiant mostly exhibit the same general characteristics year after year. There are, however, considerable differences between various showers. In some, the meteors move very swiftly, in others, they move comparatively slowly; in some, the average meteor is faint, in others, a proportion of fireballs may be expected. Streaks or trails are characteristic of some showers, while occasionally a bright slow-moving meteor seems to travel in a wavy path. All these points should be noted in meteor observations, but in recording the appearance of a meteor, the unskilled should note that it is much more important to describe exactly its apparent path or track among the stars, from beginning to end, than its physical appearance. The same shower may also vary considerably in point of numbers, being quite conspicuous one year, and hardly visible the next, or for years in succession. On the other hand, some showers of considerable steadiness sometimes flash into great activity at intervals, the Leonids for instance.

Meteors are generally twice as frequent at 6 a.m. as at 6 p.m., because at the former hour we are facing in the direction of the Earth's motion in its orbit; in the latter, to the rear. They usually appear from 50 to 80 miles above the Earth's surface, and, on the average, disappear at 40 or 50 miles. (See Notes on observing meteors, p. 37).

Comets vary in brightness, most of them being visible only with the aid of a telescope. A comet is generally first discernible as a minute, faint, misty patch of light, so much resembling a nebula that it is only identified as a comet when found to be in motion, but sometimes even a very large comet escapes detection at first by approaching us in the line of the sun. The essential portion of all comets is the *coma* or head, the misty patch of light already mentioned. In addition a *nucleus* may develop as it approaches the sun, *i.e.* a bright flame-like or star-like appearance within the *coma*, and also a tail, or sometimes several tails—which always point more or less away from the sun, no matter whether the comet is approaching or receding from the sun. The tail usually appears as a curved hollow cone, decreasing in brightness as it widens out. Both nucleus and tail, when present, increase in size and brightness as the comet nears the sun, and decrease as it recedes from the sun; *envelopes*, or stratifications of the mist round the nucleus, especially on the side towards the sun, may also appear as the comet approaches perihelion. Neither nucleus nor tail, however, is necessarily present. Several comets are connected in some way with meteoric showers.

Entirely new comets are usually named after their discoverer, as Donati's comet, 1858. The comets seen during any year, whether new or already known, are also denoted:—(1) by the order in which they are discovered during that year, small Roman letters being used instead of numbers: Comet 1918 *a*, was the first comet seen that year, Comet 1918 *b*, the second, and so on. (2) By the order of their arrival at perihelion, using Roman numerals, I, II, &c., as Comet 1918 I.

Periodic comets—those which revolve round the sun, and thus appear at regular intervals—are known by the name of their discoverer (as *Holmes' comet*), or discoverers at two different returns (as *Pons-Brook's comet*), or discoverer or investigator of the periodicity (as *Halley's* and *Encke's Comets*). Tempel I (1867), Tempel II (1873), indicate two discoveries by the same observer. *Biela's comet* (now lost), which divided in two, was known as Biela I and II.

The Zodiacal Light:—Except near the time of the equinoxes, this is not well seen in temperate latitudes, as its axis in the sky at other times is comparatively near the horizon. It appears as a faint, hazy, conical, beam, some 15°-20° wide at the base, which nearly follows the course of the Ecliptic (not the Celestial Equator) on the star sphere, for 90° or more from the horizon a little south (S. Hemisphere, north) of where the Sun is below the horizon; in its brightest parts, it is two or three times as luminous as the Milky Way, but towards its extreme limits it is always exceedingly faint. Its brightness seems to vary from time to time, and it is brighter when observed within the tropics than in temperate latitudes, partly owing to its being more nearly vertical to the horizon, and partly to the shorter duration of twilight. It is best seen Feb.-March (evening), Aug.-Sept. (morning) in the N. Hemisphere; in the S. Hemisphere, *vice versa*; the inexperienced are apt to mistake the glow of twilight for it. (See Notes on Observing). In a very clear atmosphere, the *Zodiacal Band*, a narrower extension, joins the *Gegenschein* (next page), thus extending the Light right round the star sphere. These phenomena are all usually attributed to sunlight reflected from meteoric bodies, their spectra being mainly that of sunlight, but two recent theories consider them, (a) a terrestrial 'tail,' like that of a comet, due to the Sun's light-pressure; (b) an atmospheric phenomenon at an immense altitude.

The 'Counter glow' or *Gegenschein* is a *very* faint round patch of light, 10° - 20° in diameter (*i.e.*, larger than the 'Great Square of Pegasus' = α, β, γ , PEGASI and α ANDROMEDÆ), or 40° - 60° according to another authority, situated on the Ecliptic at the point diametrically opposite to where the Sun is for the time being. It is very difficult to see, and cannot be distinguished if projected on the Milky Way: choose a moonless night of exceptional clearness, when the Ecliptic is highest above the horizon, viz., in December and January. According to Barnard, it is largest and brightest in September and October. (See a long paper by Barnard, in the *English Mechanic*, March 21, 1919). It also is probably due to sunlight reflected from meteoric bodies.

Occultations take place when the Moon or a planet passes directly between us and some other heavenly body, shutting it out from view. Occultations of stars by the Moon are frequent, and their times are given in almanacs: the disappearance, or *immersion*, always takes place on the east side of the Moon and the reappearance, or *emersion*, on the west side. Where the star occulted is bright, the disappearance and reappearance, being instantaneous, are of great interest, especially at the dark limb; on rare occasions the star seems to hang for an instant on the limb, perhaps chancing on some irregularity. Only those stars within about $6\frac{1}{4}^{\circ}$ of the Ecliptic can be occulted (and these only in 9-18 yr. cycles, p. 8); the Moon's great parallax, also, nearly 1° , restricts an occultation to a limited area on the Earth.

The *Defect of Illumination*, is the extent of the Moon's or of a planet's dark phase, which in occultations results in the star (or Jupiter's satellite) disappearing before the bright disc is reached, or re-appearing some distance away.

Eclipses.—*Eclipses of satellites* differ from their occultations, in taking place when they enter the *shadow* of their planet, and are invisible merely because the Sun no longer shines on them, though nothing intervenes between them and us.

In *Solar Eclipses*—which, strictly speaking, are really occultations of the Sun—the eclipse begins on the west side of the Sun's disc, and the shadow sweeps across the Earth's surface from west to east; in *Lunar Eclipses*, the eclipse begins on the east side of the disc, and sweeps over it westwards. The *umbra*, or *shadow*, is the dark shadow on that portion of the Earth in solar, of the Moon in lunar eclipses, which, for the time being, receives no direct light from the Sun. The umbra shades away into the bordering *penumbra* or partial shadow, which covers those regions of the Earth or Moon whence the Sun would be seen partially eclipsed: the edge between them is never sharply defined.

First Contact occurs, in a solar eclipse, at the instant when the discs of the Sun and Moon first appear to touch, *i.e.*, when the eclipse begins: *Last Contact* at the instant of the end of the eclipse. In the case of a lunar eclipse, we have two First Contacts—at the instant when (1) the penumbra, and (2) the umbra or shadow, first touch the Moon's disc; and similarly two Last Contacts, at the moment when (3) the shadow, and (4) the penumbra respectively leave the disc.

The *magnitude*, or extent, of partial and annular eclipses is indicated by expressing the proportion of the diameter eclipsed as a decimal of the full diameter, at the time, of the Sun's or Moon's disc; in solar eclipses it varies according to the locality, but in lunar eclipses it is the same at any place from which it is visible.

In a total lunar eclipse, the magnitude is indicated as the ratio to the Moon's diameter at the time taken as 1; any eclipse less than 1 will be a partial one, while the maximum will be about 1.8, but this only occurs when the Moon is simultaneously in perigee and on the Ecliptic. The further the Moon is from the Ecliptic, the shorter is the duration of totality, and the nearer the points of first and last contact to the lunar poles.

Lunar Eclipses, when total and central, may last as long as 3 hours 48 minutes from first to last contact of the umbra, or up to 6 hours including the penumbral stage; the maximum duration of totality is 1 hour 42 minutes. Usually the Moon does not altogether disappear from view, even at mid-eclipse, but shines with a dull reddish-orange or greyish light, being illuminated by sunlight refracted by the Earth's atmosphere: the colour and brightness depend on the amount of water vapour and clouds present in the Earth's atmosphere at the time. On rare occasions the clouds intercept all or nearly all the rays that would be refracted, so that the Moon becomes nearly or altogether invisible.

Solar Eclipses, both total and annular, are rarely visible from any given place, the 'expectation' being only one in 360 years. Some 3 or 4 hours elapse between first and last contact, but totality never exceeds 7 m. 40 secs., and annularity $12\frac{1}{2}$ minutes: both are usually much less. At the equator, both totality and contact-interval last about a quarter longer than at lat. 50° . The width of the zone of totality averages less than 100 miles, but where the Sun is in the zenith it may be about 167 miles.* Partial solar eclipses are of little interest, the Sun merely appearing notched; the temperature may fall perceptibly, however, and about mag. .97, Mercury, Venus, and stars may appear.

Transits of Mercury and Venus.—Transits of *Venus* happen twice at the short interval of eight years, and then do not recur for over 100 years ($105\frac{1}{2}$ and $121\frac{1}{2}$ alternately). Last transits, 1874, 1882; next transits, 2004, 2012.

Mercury transits the Sun about four times in 33 years, and at the same node at intervals of 7, 13, 33 or 46 years. The transits always happen at the descending node in May, or at the ascending node in November. Transits take place in May [1924], 1957, and 1970, and in November [1927], 1940, 1953, 1960 and 1973. (See Note on Transits, p. 36).

* Track Charts of important eclipses are given in the *N.A.*

V. HINTS ON OBSERVING, &c.

Atmospheric Conditions.—To get the best results, objects should be viewed when they are as far as possible above the horizon, *i.e.*, when near culmination. Satisfactory observations cannot be made of objects at low altitudes, owing to the increased intervening thickness of the atmosphere, and the haze and mist which so often obscure the horizon. The nights when the sky is darkest, and the stars most brilliant, are not always the best for observations. Faint and ill-defined objects, such as some nebulae, may, however, often be seen to advantage on such nights.

During a slight haze, the air is often very steady, and splendid views of bright objects may then be obtained. If the stars twinkle much, it indicates that the air is unsteady and not altogether satisfactory for observation.

Viewing Faint Objects.—The eye becomes much more sensitive to faint impressions after it has been kept in the dark for a considerable time. A slight change of focus is often restful to the tired eye.

Very faint objects, otherwise invisible, may sometimes be detected by averted vision: the eye is directed to another part of the field, while the attention is fixed on the spot where the object is supposed to be.

Making Notes: Consulting Charts, &c.—A bull's-eye lantern with a slide to shut off the light is of great use. A cycle lamp may be utilised by the occasional observer. A photographic red lamp is even better, as it does not affect the sensitiveness of the eye. It may be placed on a support at some distance from the observer, and so directed as to throw a *faint* light on the book or card, when notes or sketches are being made at the telescope. A strong light should be avoided, as it makes the eye less sensitive for observation.

A small table to hold the maps and other books, with a lantern having a shade to throw the light downwards, lest the direct rays of light should reach the eye, is almost a necessity; a special shelf may be fixed up in an out-house.

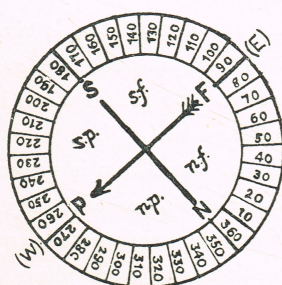
All observations should be written down at the time, when they are made. The notes should be clearly worded, and should have entered on them the year, month, day, hour, and minute of the observation, together with the aperture and power of the telescope, and the state of the air. In Earthshine observations, the temperature, barometer reading, and direction of the wind should also be noted, as meteorological conditions have some influence on the brightness.

Direction in an Inverting Telescope.—In the inverted view of an object, as seen in astronomical telescopes (except 'Gregorians'), to observers in the Northern Hemisphere the upper part of the field of view is south, while the lower part is north; east is on the right hand of the object, and west on its left side.

To observers south of the Equator the reverse is the case; the upper part of the field is north, and the lower south; east is on the left hand of the object: west, on its right.

For circumpolar stars, however (*i.e.* those a less number of degrees from the Pole than the observer), the rule does not hold, as the observer is facing the other way, and objects on opposite sides of the Pole are moving in opposite directions.

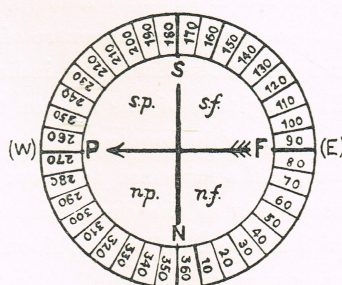
North Preceding, &c.—To get over these difficulties in describing how to find a celestial object in the field of view, the phrases 'North (or South) preceding,' 'North (or South) following,' a certain star, are commonly used. *North* (or *South*) indicates that the object is nearer the North (or South) celestial pole than the star referred to; *Preceding* that its Right Ascension is *less* than that of the reference star, and *Following*, that its R.A. is *greater*, thus indicating the



Between rising and culmination.

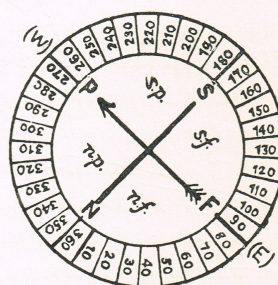
(Angle depending on latitude of observer and declination of star).

n.p.=North preceding. n.f.=North following. s.p.=South preceding. s.f.=South following. P=West. F=East.



Southing or culminating.

(Upright).



Between culmination and setting.

(Angle depending on latitude of observer and declination of star).

direction in which to find the required object. The annexed diagram indicates how the hour-circle—which coincides with the line SN in the diagram—lies with respect to the horizon in an inverting telescope, when in different positions, and how a Position angle (P.A.) will in consequence occupy varying positions in the field of view.

In the diagram, the arrow denotes the apparent path of a star with reference to the horizon, as it crosses the field of view of a fixed inverting telescope in the N. Hemisphere. This path will be horizontal only when the object is on the meridian, but the relative positions remain unchanged. In the S. Hemisphere, hold the book upside down.

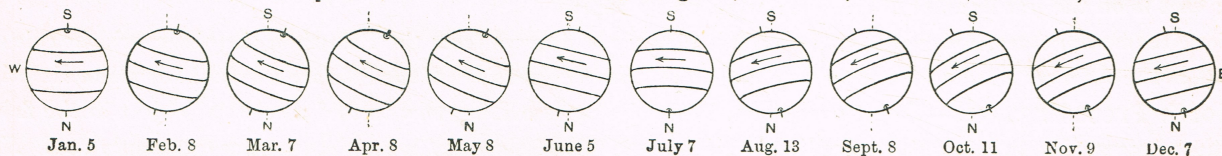
Observing the Sun.—It is extremely dangerous to attempt to view the Sun unless proper precautions are taken: blindness may be the penalty of rashness or ignorance. A perfectly safe method is to support a smooth, white card, at the distance of about a foot from the eye-piece, and to focus the image of the Sun projected on it. The screen should be held in a covered frame-work or box, and the picture of the Sun viewed through a hole in one of the sides. If, on the other hand, the Sun is viewed directly through a dark-glass cap, a larger aperture than 2 inches cannot safely be used in the heat of summer. A stop made of a card, with a circular hole of 2 inches or less in diameter, should be fitted over the object glass of a larger instrument, to reduce the amount of light and heat transmitted: this, however, tends to reduce the sharpness of the definition. A special solar eye-piece can be obtained which enables full apertures to be used with safety.

Observing Prominences, by the spectroscope. The edge of the Sun's image should be made to fall on the nearly-closed slit of the spectroscope—which must be one of considerable dispersive power. The telescope should then be driven (preferably by clockwork) so as to keep the image in the same position. The spectroscope is next focussed on one of the hydrogen lines of the spectrum, and, on the slit being opened, the prominence will be seen. Good views may be obtained in this way, using a 3-inch telescope with a spectroscope having several prisms.

Observing Sunspots.—In studying their motion across the disc from east to west (see note, p. 33, as to direction in inverting telescopes), the position angle (p. 5) of the Sun's axis requires to be taken into consideration, as the apparent path varies according to the time of the year. The spots only move in straight lines across the disc about June 5 and December 7, on which dates alone the solar equator is seen as a straight line on the disc, dividing it into two hemispheres, with the poles exactly on the limb. At all other times, one pole alone is visible—very near the limb owing to foreshortening—and the solar equator lies on one side or other of the apparent centre of the disc, and is curved downwards or upwards, as are also the paths of the spots: maximum curvature northwards, about March 7; southwards, about Sept. 8. Sunspots take about a fortnight to traverse the disc from limb to limb,* and will reappear after the same interval if they survive. Naked-eye spots have a diameter not less than about 1/60th of the disc (31").

The variation of the position angle of the Sun's axis during the year (for the *North* pole) is about as follows:—

Jan. 5, July 7, 0°	Feb. 23, May 19, 20° W.	July 7, Jan. 5, 0°	Aug. 28, Nov. 20, 20° E.
„ 16, June 26, 5° W.	Mar. 7, May 8, 23° W.	„ 19, Dec. 26, 5° E.	Sept. 8, Nov. 9, 23° E.
„ 27, „ 15, 10° W.	„ 18, Apr. 26, 25° W.	„ 30, „ 16, 10° E.	„ 21, Oct. 30, 25° E.
Feb. 8, June 5, 14° W.	April 8, ... 26° 42' W.	Aug. 13, Dec. 7, 14° E.	Oct. 11, ... 26° 42' E.



The distance of the Sun's visible pole from the limb has necessarily been exaggerated in the diagram. N, S, indicate the line of the hour circle, N showing North in an inverting telescope—nearest the horizon in the N. Hemisphere. In the S. Hemisphere, hold the book upside down.

Near the times of the greatest inclination of the axis to the hour-circle, spots just appearing on the limb in the high spot-latitude of 45°, are, by the inexperienced, apt to be taken as being near the poles.

The number of degrees the solar equator is below or above the centre of the disc on various dates, is given in the *Nautical Almanac*, column B₀, 'Heliographic Latitude of the Earth,' + indicating that the spot-path is curved southwards, and - that it is curved northwards. The longitude of the spot on the surface can be found when it arrives half-way across the disc, from the column L₀, 'Heliographic longitude of the centre of the disc.'

Observing the Moon.—With a low power, and a fair-sized telescope, the glare of the Moon is very trying to the eye, and a tinted glass, mounted in the same way as the dark glass of the solar eye-piece cap, may be used. Reducing the aperture affects the sharpness of the definition. When the Moon is in perigee, the brightness is appreciably greater than when she is in apogee, the ratio being nearly as 4 is to 3. Best-seen conditions of each phase, see p. 47.

Observing Lunar Eclipses.—Mid-winter eclipses have the best altitude conditions, mid-summer ones the least favourable, for the reason given p. 47. First contact is always on the E. side of the disc, and through the telescope the Earth's shadow may be seen sweeping slowly across it, but the edge is not sharply defined. It should be noticed that from first to last, the 'preceding' edge of the umbra is always uniformly convex, unlike the dark terminator of the young Moon, which, though convex at first, daily grows less convex, till, at First Quarter, it is straight, and finally becomes increasingly concave. Similarly, the 'following' edge of the umbra is also always convex. Phenomena that may be noted are the visibility or otherwise of the rays, and of prominent craters, &c., such as Aristarchus and Copernicus: also the variations of colour as the eclipse progresses, on different parts of the disc.

* Stonyhurst discs, for measuring the positions of sunspots and faculae by projection, can be obtained from Messrs Casella & Co., Southampton St., Fitzroy Sq., London, S.W.1. For the method of using them see 'Memoirs of the Brit. Astr. Assn., Vol. XXIII., Part II.'

Observing the Superior Planets.—In temperate latitudes, summer observations of these planets are always conducted under unfavourable conditions as to altitude; in winter, the altitude conditions are the most favourable. This results from the planets being always near the Ecliptic, so that their highest altitude above the observer's horizon at culmination is much the same as that of the Ecliptic where it cuts his meridian. At mid-summer, mid-night culmination is at its lowest, and in mid-winter at its highest. Thus observers in the Northern hemisphere, outside the tropics, are better situated for observing the oppositions between October and March, than those in the Southern hemisphere, while observers in the latter are better placed for seeing oppositions between April and September.

A curious effect of the two-year synodic period of Mars is, that for some eighteen months or so in succession, he is visible at some time or other every night, then becomes lost in twilight and daylight for some four or six months.

The angular diameter, or semi-diameter, of a planet's disc on any date, will be found in almanacs: the diagram indicates, on a uniform scale, the range of changes, and relative sizes, of the discs, and the favourableness, or otherwise, of the size of the disc can easily be inferred by reference to the mean diameter.



Saturn. Min. 15" Mean. 18" Max. 21". Uranus. 3½". Mars. Min. 3½" Mean. 15" Mean. opp. 19" Max. 25". Jupiter. Min. 30" Mean. 40" Max. 50".

Observing Mercury and Venus.—The most favourable seasons of the year are indicated on page 25. For Mercury, Southern observers have the best conditions, as his maximum elongation occurs when he is in S. Declination.

Observing Occultations.—Beginners will probably be rather puzzled to know the direction in which the Moon will approach the star, owing to the varying position of the Moon's axis with respect to the horizon: the direction, however, is approximately at right angles to the line joining the cusps, or horns of the Moon, unless the Moon is very young or very old, and far from the Ecliptic. The rate of approach is about a quarter of the Moon's diameter in 14 minutes, or the apparent diameter of Hipparchus in about 2¾ minutes, or of Copernicus in about 1½ minutes. The positions of disappearance, &c., with reference to the North point (p. 5), are given in the *Nautical Almanac*; also—if the Moon is above the observer's horizon—the parallels of latitude within which the occultation will be visible: the Moon's parallax being nearly 1°, and her diameter only 32', the star will not be occulted N. or S. of these latitudes.

Observing the Zodiacal Light.—As the axis of the Light approximately coincides with the Ecliptic, the most favourable conditions in temperate latitudes are when the Ecliptic is most nearly vertical to the horizon soon after sunset, or before sunrise, which in the evening is before the Spring equinox, and in the morning after the Autumnal equinox, of each hemisphere. The nearest approach to verticality is always when 6 hrs. R.A. is on the meridian (N. Hemisphere), or 18 hrs., (S. Hemisphere); at that instant, too, both the direction of the lowest portion of the Light, also the verticality, are most easily found, as the Ecliptic then intersects the horizon exactly due west and due east,* and its angle with the horizon is equal to the co-latitude of the observer *plus* 23½°.

The Zodiacal Light proper cannot be longer above the horizon than six hours after sunset, or before sunrise, as its extension from the Sun is reckoned as about 90°, but of course it will only be distinguishable for a much shorter period, twilight preventing observation for perhaps an hour after sunset, in the higher temperate latitudes; and the haze of the horizon obscuring its faint extremity for long before setting. For brightness, compare with Milky Way.

The Table below gives the approximate dates and hours when the Ecliptic is most nearly vertical during the short observing season. The dates at the top are for the N. Hemisphere; those at the foot (in *italic*) for the S. Hemisphere. The position of the foot of the Light on the horizon for three or four hours after (or before) the hours mentioned is easily found, as its movement in azimuth westwards, may be taken as about 6° per hour, over that period; similarly, the decrease per hour in inclination after (or before) greatest verticality is, roughly, 2°.

Feb. 5	Feb. 12	Feb. 20	Feb. 27	Mar. 7	Mar. 14	Mar. 22	Sept. 22	Sept. 29	Oct. 7	Oct. 14	Oct. 22	Oct. 30	Nov. 7
9 p.m.	8:30	8 p.m.	7:30	7 p.m.	6:30	6 p.m.	6 a.m.	5:30	5 a.m.	4:30	4 a.m.	3:30	3 a.m.
<i>Aug. 6</i>	<i>Aug. 13</i>	<i>Aug. 21</i>	<i>Aug. 29</i>	<i>Sept. 6</i>	<i>Sept. 13</i>	<i>Sept. 21</i>	<i>Mar. 23</i>	<i>Mar. 31</i>	<i>Apr. 8</i>	<i>Apr. 15</i>	<i>Apr. 23</i>	<i>Apr. 30</i>	<i>May 8</i>

Duration of Twilight.—Twilight is conventionally reckoned as ending when the Sun is 18° perpendicularly below the horizon, but it has no definite duration, as meteorological conditions may prolong or shorten it. The glow in its later stage is the segment of a circle with a radius of about 18°, described from the Sun as centre, which gradually sinks below the horizon, the brightness being greatest vertically above the Sun. Except in high latitudes, there is little variation in the duration of twilight throughout the autumn, winter, and spring portion of the year; it is shortest all over the Earth about the time of the equinoxes; but it lengthens with approach to either solstice.†

Latitude,	0°	10°	20°	30°	40°	45°	50°	55°	60°
Winter Solstice	1h. 16m.	1h. 17m.	1h. 19m.	1h. 26m.	1h. 39m.	1h. 48m.	2h. 1m.	2h. 19m.	2h. 48m.
Equinoxes ...	1 8	1 10	1 14	1 20	1 30	1 39	1 50	2 5	2 26
Summer Solstice	1 15	1 17	1 24	1 36	2 03	2 33	Lasts from	Sunset to	Sunrise.
Distance of Sun below horizon at midnight, Summer Solstice ...							about 16°	11°	6°

* In finding E. and W., note that the compass-direction requires correction for the magnetic variation; see 1-inch Government Maps.

† Twilight Tables now given in *N.A.*

Observing Variable Stars.—The 'variable' is compared with neighbouring stars of similar brightness and of known magnitude. Two comparison stars are found, one rather brighter than the variable, the other slightly fainter; the magnitude of the variable will be between those of the comparison stars, and the nearer their magnitudes, the more accurate the result. Except for rough estimates, a catalogue of magnitudes is required, or a special star chart, such as those for Novæ and interesting variables given from time to time in the British Astron. Association Journal, or 'sequences,' *i.e.*, lists of standard stars, arranged in order of magnitude for this purpose.

The dates of maxima and minima are recorded by the Julian Day (J.D.)*—which begins at *noon*, not midnight, (p. 7)—and decimals of a day, but observations cannot always be made, as the date may fall when the star is near the Sun, or during moonlight. The annual B.A.A. Handbook gives useful observing information, dates of maxima, &c.

It is important, where possible, (a) to observe the star when at its highest altitude; (b) that the comparison stars be about the same altitude, so that atmospheric absorption (see below) will equally affect their magnitudes; (c) that they be as nearly as possible similar in colour to the variable, as it is very difficult to estimate correctly the real relative brightness of two stars differing widely in colour, as, for instance, in the case of Betelgeuse and Rigel. For a curious optical phenomenon—known as the *Purkinje Effect*—comes into play, namely, that if red and green lights, appearing equally bright, are increased or decreased in the same ratio, in neither case will they now appear of equal brightness; the red will seem the brighter when the light is increased, but the green when the light is decreased.

Estimating Magnitudes: Atmospheric Absorption.—For accurate valuation of the magnitudes of bright variable stars, if the comparison stars are not about the same altitude, allowance must be made for the difference, as atmospheric absorption diminishes the brightness (apart from haze) by approximately the following magnitudes:—

Zenith distance.	47°	58°	64°	69°	71°	73°	75°	77°	79°	80°	84°	86°	88°	89°
No. of mags. diminished.	$\frac{1}{10}$ th	$\frac{2}{10}$ ths	$\frac{3}{10}$ ths	$\frac{4}{10}$ ths	$\frac{5}{10}$ ths	$\frac{6}{10}$ ths	$\frac{7}{10}$ ths	$\frac{8}{10}$ ths	$\frac{9}{10}$ ths	1 mag.	1½m.	2m.	2½m.	3m.
Altitude above horizon.	43°	32°	26°	21°	19°	17°	15°	13°	11°	10°	6°	4°	2°	1°

Comet Seeking.—In searching for comets, a telescope of fairly large aperture and of short focal length, with an eye-piece of low power having a large field of view, should be used. The observer should slowly 'sweep' (*i.e.*, move the telescope in a horizontal direction) for some distance, a careful watch being kept all the time. At the end of the sweep the telescope is *slightly* raised or lowered, and an overlapping sweep is taken in the opposite direction. This process is repeated continuously. Should a nebulous-looking object be noticed, the comet-hunter must look in his catalogue of nebulae to see if the object can be identified. If not, he should draw a careful sketch of its position among the neighbouring stars. If in the course of time any movement can be detected, and the place of the suspected object does not agree with that of any known comet, its position should be determined as accurately as means will allow, and a telegram giving particulars should be sent to Greenwich (or the corresponding) Observatory.

Observing Transits.—There are four contacts: *external contact*, at ingress and egress, *i.e.*, entering or leaving the Sun's or planet's limb; and *internal*, when entering completely on or beginning to depart from, the disc.

The Black Drop, seen at internal contact when Venus (sometimes Mercury) is just touching the Sun's limb, is a curious drawing-out of the planet's black disc to the Sun's limb, in a broad band or ligature, which gives it the appearance of a drop of black ink hanging internally from the Sun's limb. In a few seconds the band contracts, then breaks: this renders the instant of internal contact uncertain. A very narrow brilliant circle of light is sometimes seen surrounding Venus near first and last contacts; it is probably due to sunlight refracted by her atmosphere.

Decimals of a Day.—The decimals of a minute (1st column) serve for the rest: add the decimal *in the same line*.

Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. h. m.	Dec. min.
·01 0 14·4	·11 2 38	·21 5 2	·31 7 26	·41 9 50	·51 12 14	·61 14 38	·71 17 2	·81 19 26	·91 21 50	·001 21 50	·002 22 4	·003 22 19	·004 22 33	·005 22 48	·006 23 2
·02 0 28·8	·12 2 52	·22 5 16	·32 7 40	·42 10 4	·52 12 28	·62 14 52	·72 17 16	·82 19 40	·92 22 4	·002 22 4	·003 22 19	·004 22 33	·005 22 48	·006 23 2	·007 23 16
·03 0 43·2	·13 3 7	·23 5 31	·33 7 55	·43 10 19	·53 12 43	·63 15 7	·73 17 31	·83 19 55	·93 22 19	·003 22 19	·004 22 33	·005 22 48	·006 23 2	·007 23 16	·008 23 31
·04 0 57·6	·14 3 21	·24 5 45	·34 8 9	·44 10 33	·54 12 57	·64 15 21	·74 17 45	·84 20 9	·94 22 33	·004 22 33	·005 22 48	·006 23 2	·007 23 16	·008 23 31	·009 23 45
·05 1 12·0	·15 3 36	·25 6 0	·35 8 24	·45 10 48	·55 13 12	·65 15 36	·75 18 0	·85 20 24	·95 22 48	·005 22 48	·006 23 2	·007 23 16	·008 23 31	·009 23 45	·010 24 0
·06 1 26·4	·16 3 50	·26 6 14	·36 8 38	·46 11 2	·56 13 26	·66 15 50	·76 18 14	·86 20 38	·96 23 2	·006 23 2	·007 23 16	·008 23 31	·009 23 45	·010 24 0	·011 24 14
·07 1 40·8	·17 4 4	·27 6 28	·37 8 52	·47 11 16	·57 13 40	·67 16 4	·77 18 28	·87 20 52	·97 23 16	·007 23 16	·008 23 31	·009 23 45	·010 24 0	·011 24 14	·012 24 28
·08 1 55·2	·18 4 19	·28 6 43	·38 9 7	·48 11 31	·58 13 55	·68 16 19	·78 18 43	·88 21 7	·98 23 31	·008 23 31	·009 23 45	·010 24 0	·011 24 14	·012 24 28	·013 24 42
·09 2 9·6	·19 4 33	·29 6 57	·39 9 21	·49 11 45	·59 14 9	·69 16 33	·79 18 57	·89 21 21	·99 23 45	·009 23 45	·010 24 0	·011 24 14	·012 24 28	·013 24 42	·014 24 56
·10 2 24·0	·20 4 48	·30 7 12	·40 9 36	·50 12 0	·60 14 24	·70 16 48	·80 19 12	·90 21 36	·00 24 0	·010 24 0	·011 24 14	·012 24 28	·013 24 42	·014 24 56	·015 25 10

Hours and Minutes as Decimals of a Day.

Hrs.	½ hr.	1 h.	1½ h.	2 h.	2½ h.	3 h.	3½ h.	4 h.	4½ h.	5 h.	5½ h.	6 h.	6½ h.	7 h.	7½ h.	8 h.	8½ h.	9 h.
= ·0208 d	·0417	·0625	·0833	·1042	·1250	·1458	·1667	·1875	·2083	·2292	·2500	·2708	·2917	·3125	·3333	·3542	·3750	
9½ h.	10 h.	10½ h.	11 h.	11½ h.	12 h.	12½ h.	13 h.	14 h.	15 h.	16 h.	17 h.	18 h.	19 h.	20 h.	21 h.	22 h.	23 h.	
= ·3958 d	·4167	·4375	·4583	·4792	·5000	·5208	·5417	·5625	·5833	·6042	·6250	·6458	·6667	·6875	·7083	·7292	·7500	
Minutes:—	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.	10 m.	11 m.	12 m.	13 m.	14 m.	15 m.	16 m.	17 m.	
Decimal=	·0007 d	·0014	·0021	·0028	·0035	·0042	·0049	·0056	·0062	·0069	·0076	·0083	·0090	·0097	·0104	·0111	·0118	
18 m.	19 m.	20 m.	21 m.	22 m.	23 m.	24 m.	25 m.	26 m.	27 m.	28 m.	29 m.	30 m.	35 m.	40 m.	45 m.	50 m.	55 m.	
=	·0125 d	·0132	·0139	·0146	·0153	·0160	·0167	·0174	·0181	·0187	·0194	·0201	·0208	·0215	·0222	·0229	·0236	

* Sometimes 'J.A.D.', Julian Astronomical Day.

Observing Meteors.—Showers from radiants within or near the circle of the 'always-seen' stars of any locality are observable all night, more or less, but the observing interval shortens as the distance from that circle increases, until, for the more remote, should the culmination-hour be many hours after midnight, the shower is never observable from that latitude except for a few hours before sunrise. Thus the November Leonid shower is only a morning one as the radiant culminates about 6 a.m., and only rises about midnight. Some meteors from a radiant just below the horizon may be visible, however. The possible observing-hours can be found from the star Table on page v.

The following are the important points to note:—Date; Greenwich Mean Time (G.M.T., G.C.T.) of appearance; R.A. and Dec. of beginning and end of flight, and duration in seconds; colour and stellar magnitude, stating comparison star; path, if straight or wavy; streak or train, if any, and the colour, duration, direction and speed of drift; any other notes. A *streak* is the faint, phosphorescent narrow band, sometimes coloured, which endures for a time along the path of some meteors: a *train*, a spark-like and usually quickly-disappearing appendage. The R.A. should be stated in degrees (see conversion Table below), and the observation communicated to the Director, Meteor Section of the British Astronomical Association, London,* or to the American Meteor Society.

For counting seconds, the well-known photographic rule 'One, two, three, ONE; one, two, three, TWO; &c.', pronounced rapidly but distinctly, gives very near results.

List of Important Showers.—The Radiant position may change a degree or two on successive days, and a look-out should be kept before and after the dates given, as leap year adjustments cause small variations. For a Radiant on every night of the year, see B.A.A. Handbook, 1922; and list of 1000 radiants, *Mem. R.A.S.*, vol. 53.

The column headed 'Cul.' gives the Radiant's approximate hour of culmination on the central date, 'a' denoting a.m.; 'p' p.m.

Date.	Shower.	Cul.	Radiant.		Speed, &c.	Date.	Shower.	Cul.	Radiant.		Speed. &c.
Jan. 2-3	Quadrantids	9 ^a	R.A. = h. m.	Dec.		Aug. 10-12	Perseids ¹	6 ^a	R.A. = h. m.	Dec.	
" 17	κ Cygnids	12 ^a	230°=15 20	53° N	Medium.	" 12-Oct. 2	α Aurigids	6 ^a	45°=3 0	57° N	v. swift.
Feb. 5-10	α Aurigids	8 ^p	295° 19 40	53° N	slow, trained.	Aug.-Sept.	Lacertids	12 ^p	74° 4 56	42° N	v. swift, streaks.
Mar. 10-12	ζ Boötids	3 ^a	75° 5 0	41° N	v. sl., fireballs.	" 10-20	κ Cygnids	10 ^p	332° 22 8	49° N	medium, short.
Apl. 20-22	Lyrids	4 ^a	218° 14 32	12° N	swift, streaks.	" 21-23	ο Draconids	9 ^p	290° 19 20	54° N	" bright.
May 6	γ Aquarids	7 ^a	271° 18 4	33° N	do	" 21-31	ζ "	7 ^p	291° 19 24	60° N	v. slow: max. 1879.
" 11-24	ξ Herculis	1 ^a	334° 22 16	2° S	v. swift ³ .	Sept. 7-15	ε Perseids	5 ^a	263° 17 32	62° N	slowish, bright.
" 30	η Pegasids	6 ^a	247° 16 28	28° N	swift, white.	Oct. 2	Quadrantids	3 ^p	61° 4 4	35° N	swift, streaks.
June 2-17	α Scorpiids	12 ^p	333° 22 12	27° N	v. sw., streaks	" 12-23	ε Arietids	1 ^a	230° 15 20	52° N	slow. In 1877.
" 27-30	ι Draconids	9 ^p	253° 16 52	22° S	v. sl., fireballs.	" 18-20	Orionids	4 ^a	42° 2 48	21° N	v. slow, fireballs.
" -Sept	γ do	9 ^p	228° 15 12	57° N	v. slow ⁴ .	" 30-Nov. 17	ε Taurids	1 ^a	92° 6 8	15° N	swift, streaks.
July 18-30	α Cap'cornids	12 ^p	269° 17 56	48° N	slow, trained.	Nov. 3-15	e "	12 ^p	64° 4 16	22° N	slow, fireballs.
" -Aug	α Cygnids	12 ^p	304° 20 12	12° S	v. sl., bright ⁵ .	" 13-15	Leonids ²	6 ^a	55° 3 40	13° N	v. slow, bright.
" 25-Au. 4	α-β Perseids	7 ^a	315° 21 0	48° N	sw., last long.	" 17-27	Andromedids	10 ^p	150° 10 0	22° N	v. swift: period
" 25-30	δ Aquarids	2 ^a	48° 3 12	43° N	v. sw., streaks	Dec. 10-12	Geminids	2 ^a	25° 1 40	43° N	v. slow ⁶ . [33]yrs
			339°=22 36	11° S	sl., long paths.				112°=7 28	33° N	med'm, white, rich

Notes. ¹ The Perseids are visible during July and Aug. (a rich display, max. Aug. 10-12): the radiant moves from about 2° + 41° to 68° + 61° (Androm. to Camelop.). ² The Leonids, or November meteors, are seen at their best about every 33 years: plentiful in 1799, 1833, and 1866, but the 1900 display was not brilliant owing to the disturbance of their orbit by Jupiter.

³ Long paths, before sunrise; Halley's comet. ⁴ Pons-Winnecke's comet. ⁵ Comet 1881 V. ⁶ Biela's comet.

R.A. Hours & Minutes converted into Degrees, or vice versa; 1 min. = $\frac{1}{4}$ °. (Reads continuously across page).

hrs.	0m.	4m.	8m.	10m.	12m.	15m.	16m.	20m.	24m.	28m.	R.A.	30m.	32m.	36m.	40m.	44m.	45m.	48m.	50m.	52m.	56m.	hrs.
0	...	1°	2°	2 $\frac{1}{2}$ °	3°	3 $\frac{1}{2}$ °	4°	5°	6°	7°	0h.	7 $\frac{1}{2}$ °	8°	9°	10°	11°	11 $\frac{1}{2}$ °	12°	12 $\frac{1}{2}$ °	13°	14°	0
1	15°	16	17	17 $\frac{1}{2}$	18	18 $\frac{1}{2}$	19	20	21	22	1	22 $\frac{1}{2}$	23	24	25	26	26 $\frac{1}{2}$	27	27 $\frac{1}{2}$	28	29	1
2	30	31	32	32 $\frac{1}{2}$	33	33 $\frac{1}{2}$	34	35	36	37	2	37 $\frac{1}{2}$	38	39	40	41	41 $\frac{1}{2}$	42	42 $\frac{1}{2}$	43	44	2
3	45	46	47	47 $\frac{1}{2}$	48	48 $\frac{1}{2}$	49	50	51	52	3	52 $\frac{1}{2}$	53	54	55	56	56 $\frac{1}{2}$	57	57 $\frac{1}{2}$	58	59	3
4	60	61	62	62 $\frac{1}{2}$	63	63 $\frac{1}{2}$	64	65	66	67	4	67 $\frac{1}{2}$	68	69	70	71	71 $\frac{1}{2}$	72	72 $\frac{1}{2}$	73	74	4
5	75	76	77	77 $\frac{1}{2}$	78	78 $\frac{1}{2}$	79	80	81	82	5	82 $\frac{1}{2}$	83	84	85	86	86 $\frac{1}{2}$	87	87 $\frac{1}{2}$	88	89	5
6	90	91	92	92 $\frac{1}{2}$	93	93 $\frac{1}{2}$	94	95	96	97	6	97 $\frac{1}{2}$	98	99	100	101	101 $\frac{1}{2}$	102	102 $\frac{1}{2}$	103	104	6
7	105	106	107	107 $\frac{1}{2}$	108	108 $\frac{1}{2}$	109	110	111	112	7	112 $\frac{1}{2}$	113	114	115	116	116 $\frac{1}{2}$	117	117 $\frac{1}{2}$	118	119	7
8	120	121	122	122 $\frac{1}{2}$	123	123 $\frac{1}{2}$	124	125	126	127	8	127 $\frac{1}{2}$	128	129	130	131	131 $\frac{1}{2}$	132	132 $\frac{1}{2}$	133	134	8
9	135	136	137	137 $\frac{1}{2}$	138	138 $\frac{1}{2}$	139	140	141	142	9	142 $\frac{1}{2}$	143	144	145	146	146 $\frac{1}{2}$	147	147 $\frac{1}{2}$	148	149	9
10	150	151	152	152 $\frac{1}{2}$	153	153 $\frac{1}{2}$	154	155	156	157	10	157 $\frac{1}{2}$	158	159	160	161	161 $\frac{1}{2}$	162	162 $\frac{1}{2}$	163	164	10
11	165	166	167	167 $\frac{1}{2}$	168	168 $\frac{1}{2}$	169	170	171	172	11	172 $\frac{1}{2}$	173	174	175	176	176 $\frac{1}{2}$	177	177 $\frac{1}{2}$	178	179	11
12	180	181	182	182 $\frac{1}{2}$	183	183 $\frac{1}{2}$	184	185	186	187	12	187 $\frac{1}{2}$	188	189	190	191	191 $\frac{1}{2}$	192	192 $\frac{1}{2}$	193	194	12
13	195	196	197	197 $\frac{1}{2}$	198	198 $\frac{1}{2}$	199	200	201	202	13	202 $\frac{1}{2}$	203	204	205	206	206 $\frac{1}{2}$	207	207 $\frac{1}{2}$	208	209	13
14	210	211	212	212 $\frac{1}{2}$	213	213 $\frac{1}{2}$	214	215	216	217	14	217 $\frac{1}{2}$	218	219	220	221	221 $\frac{1}{2}$	222	222 $\frac{1}{2}$	223	224	14
15	225	226	227	227 $\frac{1}{2}$	228	228 $\frac{1}{2}$	229	230	231	232	15	232 $\frac{1}{2}$	233	234	235	236	236 $\frac{1}{2}$	237	237 $\frac{1}{2}$	238	239	15
16	240	241	242	242 $\frac{1}{2}$	243	243 $\frac{1}{2}$	244	245	246	247	16	247 $\frac{1}{2}$	248	249	250	251	251 $\frac{1}{2}$	252	252 $\frac{1}{2}$	253	254	16
17	255	256	257	257 $\frac{1}{2}$	258	258 $\frac{1}{2}$	259	260	261	262	17	262 $\frac{1}{2}$	263	264	265	266	266 $\frac{1}{2}$	267	267 $\frac{1}{2}$	268	269	17
18	270	271	272	272 $\frac{1}{2}$	273	273 $\frac{1}{2}$	274	275	276	277	18	277 $\frac{1}{2}$	278	279	280	281	281 $\frac{1}{2}$	282	282 $\frac{1}{2}$	283	284	18
19	285	286	287	287 $\frac{1}{2}$	288	288 $\frac{1}{2}$	289	290	291	292	19	292 $\frac{1}{2}$	293	294	295	296	296 $\frac{1}{2}$	297	297 $\frac{1}{2}$	298	299	19
20	300	301	302	302 $\frac{1}{2}$	303	303 $\frac{1}{2}$	304	305	306	307	20	307 $\frac{1}{2}$	308	309	310	311	311 $\frac{1}{2}$	312	312 $\frac{1}{2}$	313	314	20
21	315	316	317	317 $\frac{1}{2}$	318	318 $\frac{1}{2}$	319	320	321	322	21	322 $\frac{1}{2}$	323	324	325	326	326 $\frac{1}{2}$	327	327 $\frac{1}{2}$	328	329	21
22	330	331	332	332 $\frac{1}{2}$	333	333 $\frac{1}{2}$	334	335	336	337	22	337 $\frac{1}{2}$	338	339	340	341	341 $\frac{1}{2}$	342	342 $\frac{1}{2}$	343	344	22
23	345	346	347	347 $\frac{1}{2}$	348	348 $\frac{1}{2}$	349	350	351	352	23	352 $\frac{1}{2}$	353	354	355	356	356 $\frac{1}{2}$	357	357 $\frac{1}{2}$	358	359	23

* Address: 136 Rodenhurst Road, Clapham Park, London, S.W.4.

Observing Novæ.—The following changes generally occur in the spectra and colour; there may be considerable variations from the normal, some stages missing, and individual peculiarities. I. A. U. Notation (1922, 1928) below.

- | | | |
|---|-------------------------------------|---------------------------------|
| 1. Continuous spectrum : White | 5. Hydrogen lines brighten up : Red | 8. Star now a planetary nebula. |
| 2. Hydrogen lines double: bright & dark lines: ,, | 6. Hydrogen lines fade : ... Orange | 9. Nebula lines fade: spectrum |
| 3. Lines widen : continuous spectrum fades. | 7. Nebula lines more prominent | now faintly continuous, |
| 4. Nebula lines appear : Yellow | than hydrogen ones, ... Bluish | bright Wolf-Rayet bands. |

Qa; absorption lines and bright bands (faint). **Qb**; stronger absorp. lines (mainly enhanced metallic, many double) and bright bands. **Qc**; absorption metallic lines of *O, N, He*, enhanced metallic lines predominating. **Qd**; as *Qc*, but gaseous lines predominating. **Qu**; broad nebulous emission bands near $\lambda\lambda 3480, 4515, 4640$. **Qx**; bright bands (enhanced *O, N, He*); absorption lines faint. **Qy**; as *Qx*, bright nebular bands. **Qz**; bright nebular and weak Wolf-Rayet bands. **Qz-50**; as *Qz*, Wolf-Rayet bands strong. Combination spectra indicated by combining the small letters, placing the most prominent first.

Observing Nebulæ.—These faint objects lose least light by atmospheric absorption when near the zenith, hence those showing a preference for the Galactic plane are most favourably situated when the Milky Way is nearly overhead, but those showing a preference for the Galactic poles, when the Milky Way lies near the horizon (see opposite).

Observing Earthshine.—The degree of visibility of the outlines of the Maria, and of Aristarchus, Copernicus, and other prominent craters, affords a good index of the state of the atmosphere. The thermometer and barometer readings, and direction of the wind should be noted, as meteorological conditions have some influence on the brightness.

To find when a Star is on the Meridian.—The R.A. Central Meridian of each Chart is given at the side.

Central Meridian Maps = R.A.	
3-4	24 h.
5-6	4 h.
7-8	8 h.
9-10	12 h.
11-12	16 h.
13-14	20 h.

(1). When will the constellation Taurus be south at 10 p.m.? From the Index of Constellations (last page) Taurus is in Map 5, the central meridian of which (see at side) is R.A. 4 h. In the Table opposite, in the column headed 10 p.m., in line with 4 h. R.A., is the date required, December 21.

(2). What constellations are in the south at 8 p.m. on March 22? Find the date, March 22; in the column headed 8 p.m., in same line, is R.A. 8 h.; = Maps 7 & 8 then south, containing Gemini, Cancer, &c.

(3). When will R.A. 6h. be on the meridian on March 7? *Ans.*, 7 p.m.—above R.A. 6h. in line with Mar. 7.

Star Catalogues are mostly found only in the annals of observatories or astronomical societies. They are of two types: (a) *Catalogues of precision*, giving the positions with all possible accuracy; (b) *Durchmusterungen*, designed to give star positions to mag. 9 with moderate accuracy only. A survey of star catalogues from the time of the earliest Greek astronomers till well on in the 19th century, will be found in the *Memoirs R.A.S.*, Vol. 43. See also Valentiner's *Handwörterbuch der Astronomie*. Some notes on catalogues are given below, and their contractions on p. vii.

In star catalogues, the + and - signs for precession and proper motion are added algebraically, so that in correcting the star's place, *like signs are added, unlike signs subtracted*.

General Catalogues.—The most complete catalogue of precision is that of the Astronomische Gesellschaft (A.G.C.), which gives positions for all stars to mag. 9, N. of 20° S. Dec.

Boss's Preliminary General Catalogue (P.G.C.) 1910 (Pub. Carnegie Inst., No. 115), gives accurate positions and proper motions of all naked-eye stars. A more extended one is in preparation.

The Henry Draper Catalogue (H.D.), gives the positions, magnitudes, and spectral type of 225,000 stars to about magnitude 10 (*H.A.*, vols. 90-99; precession and proper motion data are not given). Earlier works are the Revised Harvard Photometry (H.R.) 1908, in *H.A.* vol. 50; the Harvard Photometry (H.P.), 1898; Gould's Argentine General Catalogue (C.G.A.), 1886, and Uranometria Argentina (U.A.), 1879. [by side.

Backhouse's Cat., 1911, of all naked-eye stars, is good and inexpensive; the magnitudes of various authorities are given side by side. Some 500 bright-star positions are given annually in the *N.A.* The *Geschichte des Fixsternhimmels*, when completed, will contain all meridian observations made before 1900.

Parallaxes.—*Schlesinger's Catalogue* is a compilation of all published parallaxes, revised from time to time. *Boss's P.G.C.*, see above.

Proper Motions.—*Boss's P.G.C.*, see above. *Pub. Cincinnati Observ.*, vol. 18, gives all proper motions known to exceed 10" per century. The *Eigenbewegungs Lexicon*, a recent publication (*Hamburg Obs.*), gives references to all published proper motions.

Radial Velocities.—See a list of over 1000, *Ap. J.*, vol. 57.

Nebulæ and Clusters.—The standard work is the 'N.G.C.' or 'New General Catalogue' (in vol. 49, *Memoirs R.A.S.*); see also Melotte's list, *Mem. R.A.S.*, vol. 60, part v., p. 125. For lists of the Globular Clusters, see *H.A.* vol. 76, and *H.C.O. Bulletin*, 776.

Dark Nebulæ.—Barnard's Photographic Atlas of Dark Nebulæ.

Variable Stars.—See Hagen's 'Atlas Stellarum Variabilium,' with catalogue (1899-1908); various publications of Harvard College Observatory, and the Reports and Annual Handbook of the B.A.A.

Double Stars.—Burnham's General Catalogue of Double Stars (B.G.C.), and additional volumes.

The International Catalogue (Astronomical Section) was a valuable means of finding the literature available on any astronomical subject, as it indexed annually, under the various subjects, the papers in the principal astronomical publications of the world.* Houzeau's *Vade Mecum de l'Astronome* (1882) is a very good guide to earlier astronomical literature.

The Year's Progress.—See the Annual Report of the Royal Astronomical Society (Feb.), a valuable summary. The Yearbook of the Carnegie Institution gives some useful summaries.

* Discontinued 1917.

Nomenclature of Minor Planets, Variable Stars, Novæ, &c.—Systems that answered well in the early stages of discovery inevitably tend to become inadequate or unwieldy as discoveries increase, and from time to time they have to be revised. The following modifications have been made in the original systems.

Minor Planets. Each new discovery, before the number and name is given (p. 27), is temporarily assigned distinctive Roman letters, as, not infrequently, a supposed new asteroid proves to be identical with one already known. Originally a single letter sufficed, and the year; but in 1893, to meet the rapidly-increasing number of discoveries, the double form AA to AZ, BA to BZ, and so on, was introduced (I being omitted), and instead of beginning the alphabet afresh each year it was agreed to continue the 1893 series right on until ZZ was reached.

In 1907, the alphabet was begun for the second time, with the year added (1907 AA, &c.), and for the third time in 1916, but this was terminated with UA., Dec. 31, 1924. A new system was then started to enable belated discoveries to be inserted in approximately their proper place. The double alphabet now begins afresh each year; the discoveries of Jan. 1-15 are AA, AB, AC, &c.; of Jan. 16-31, BA, BB, BC, &c.; of Feb. 1-15, CA, CB, &c., the year being added in each case. If more discoveries than 25 in half a month, AA₁, AB₁, &c., will be used.

Variable Stars. Argelander designated those not otherwise lettered or numbered, in any constellation, by the Roman capital letters, R, S, T, U, V, W, X, Y, Z. After Z, the double form RR to RZ, SS to SZ, TT to TZ, and so on to ZZ, was used, which provided for 54 variable stars in any constellation. As that number proved insufficient, AA to AQ, BB to BQ, and so on, was employed, J being omitted. The simplest system, which denotes the variables of each constellation by the letter V, followed by a number—thus V1 = R; V2 = S; V54 = ZZ, &c., is to be used from V³³⁵, when QZ is reached. Letters are assigned when the variability is confirmed; provisionally, Novæ and ordinary variables are now designated by a number, year, and constellation, Nova Aquilæ 1918 being 7.1918 Aquilæ, in the 'variable' discoveries of 1918.

Novæ. The older Novæ are designated by the constellation and year in which they appeared, thus, *Nova Scorpii*, 134 B.C.: some having also a 'popular' name, as *Kepler's Star*, *Tycho's Star*, &c. Modern Novæ were similarly designated till 1925: if more than one appeared in a constellation, they were numbered successively *Nova I.*, *Nova II.*, and so on, of that constellation, in order of discovery, disregarding the Novæ before 1572. As many Novæ were only discovered years after their appearance, when comparing star photographs of the same region taken at different times, this sometimes resulted in the numbers being out of order as regards date of *appearance*: the nomenclature was therefore altered to constellation and year, with the date in tenths of a year, if more than one in a year.

Primary and Secondary Stars.—The brightest star is A, the companion or companions B, C, &c., as *Sirius A* and *B*.

Comets.—See page 31.

VI. THE CARE AND USE OF THE TELESCOPE.

Astronomical Telescopes are of two kinds—refracting and reflecting. Both varieties are rated according to their 'aperture,' as the *clear* diameter of the large lens in refracting telescopes, or of the mirror in reflecting telescopes, is called.

The larger the aperture, the more powerful the telescope in 'light-gathering' power, *i.e.*, in rendering visible faint objects; and, as this power (theoretically) increases in proportion to the *square* of the diameter, a telescope of 3 inches aperture is twice as powerful as one of 2 inches, while a 4-inch has nearly twice the power of a 3-inch, or four times that of a 2-inch (actual ratios, 4, 9, 16). In refractors, however, the theoretical power falls off rapidly with increasing diameter, the ever-thickening object-glass absorbing more and more light, though reflectors under 10 ins. are not quite so powerful as refractors of equal size. For astronomical purposes, a 3-inch telescope is about the smallest that can be used with satisfaction, though pleasing views of many objects may be obtained with smaller telescopes of good quality.

<i>Diam. Object Glass (clear aperture)</i>	1 in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.	5 in.	6 in.	8 in.	10 in.	12 in.
<i>Closest star divided (approx.)</i>	4.56"	3.04"	2.28"	1.82"	1.52"	1.30"	1.14"	1.01"	0.91"	0.76"	0.57"	0.46"	0.38"
<i>Faintest star shown (mag.)</i>	9.0	9.9	10.5	11.0	11.4	11.7	12.0	12.3	12.5	12.9	13.5	14.0	14.4

THE REFRACTOR essentially consists of two convex lenses—(i) a large one of considerable focal length, known as the *object glass*, which forms at its focus an image of the distant star or other object, and (ii) a small lens of much shorter focal length: this is called the *eye-piece*, and is used to magnify the image formed by the object glass.

The **Object Glass** is the most important part of the refractor, as its excellence depends on the accuracy of the curves of the lenses, the highness of their polish, and their transparency. In all astronomical telescopes worthy of the name, the object glass is 'achromatic'; that is to say, it is composed of two (sometimes three) lenses of equal size, but made of glasses of different density. These are so proportioned as to form an image almost free from the false colours which are inevitably present when a bright object is viewed through an object glass consisting of a single lens. A good object glass requires to be treated with the most scrupulous care. Follow carefully the notes on p. 45.

THE REFLECTOR.—In this form of telescope a large, concave, parabolic-curved mirror takes the place of the object glass of the refractor. The large mirror is held in a cell at the lower end of the large tube. The rays of light from the object pass down the tube and are reflected back. The reflected, convergent rays are intercepted—

- (1) In the 'Newtonian' form of telescope, either by a small, elliptical, plane mirror ('flat'), or by a right-angled totally-reflecting prism, which reflects them at right angles through the side of the telescope to the eye-piece.
- (2) In the 'Cassegrainian' form, by a small convex mirror, which reflects them back again, through a hole in the centre of the large mirror to the eyepiece; or (3) in the 'Gregorian' form, by a small concave mirror.

The Newtonian and Cassegrainian forms give an inverted image, similar to that of the refracting telescope; the Gregorian, however, gives an erect image. An unsilvered mirror is sometimes used for solar observation.

EYE-PIECES.

As already mentioned, these are used to magnify the image formed by the object glass, or the large mirror. For very high powers, and in special cases, a single lens is sometimes used; but generally an eye-piece consists of two lenses, mounted in a short tube which screws or slips into the focussing-tube of the telescope. There are several varieties, but the most common are:—

The Huyghenian or negative eye-piece.—This is the most common form, and consists of two plano-convex lenses, having their flat surfaces towards the eye.

The Ramsden or positive eye-piece.—Which gives a ‘flatter’ field than the Huyghenian (*i.e.* the field of view visible through it is not so blurred around the edges when the centre is sharply focussed), and, when of achromatic construction, performs excellently on planets.

As seen in an astronomical telescope with either of these eye-pieces, an object is inverted. To make it appear the right way up involves the use of additional lenses, which means some loss of light and a slightly fainter image, without any compensating gain.

The magnifying power of a telescope depends entirely upon the ratio of the focal length of the object glass to that of the eye-piece: thus, with an object glass of 36 inches focal length, and an eye-piece having a focal length of $\frac{1}{2}$ inch, the magnifying power will be 72 diameters, or “power 72” as it is termed.

It is advisable to have at least three eye-pieces of different power:—

- (1). One of low power with a large “field,” (that is, showing a considerable area of the sky), for viewing comets, large and scattered clusters, and extended nebulae, magnifying 8 or 10 times per inch of aperture. Thus, on a 3 in. telescope the power may be from 25 to 30.
- (2). One of moderate power, magnifying 25 or 30 times to each inch of aperture.
- (3). One of high power, magnifying 50 or 60 times to each inch of aperture.

When experience has been gained, the observer may sometimes use eye-pieces of still higher power, but, as a rule, to advantage only on close double stars, when the telescope is of excellent quality and the atmospheric conditions are most favourable. The extreme limit of useful power is about 100 diameters per inch of aperture. It must be remembered that, as the power is increased, a corresponding apparent increase takes place in any defects of the telescope, the vibrations of the stand or ground, the rate of motion of a star across the field, and of atmospheric disturbances.

To find the focal length of the object glass or mirror.—Remove the eye-piece, and stretch a piece of semi-transparent paper over the end of the draw-tube. Point the telescope at the moon, and focus the moon’s image on the paper screen. The measured distance between the back of the object glass and the screen is, for practical purposes, the focal length of the object glass. In the Newtonian Telescope, the distance is measured from the centre of the surface of the large mirror to the centre of the surface of the flat, and thence to the screen, placed as above.

To find the focal length of a Huyghenian eye-piece.—Divide twice the product of the focal lengths of the two lenses by the sum of their focal lengths: the quotient is the focal length of an equivalent single lens.*

To find the power of an eye-piece.—Make a scale with plainly-marked equal divisions. Set this up at a considerable distance away, and, holding both eyes open, view the scale through the telescope with one eye and directly with the other. The number of divisions on the scale, covered by the magnified image of one of them, is equal to the magnifying power of the eye-piece used. For measuring low powers, a distant brick wall will take the place of the scale.

Another method.—Focus the telescope on a star. Next morning, without altering the focus, point the telescope to the bright sky. When the eye is placed about 10 inches behind the eye-piece, there will be seen a small, clearly-defined disc of light. Measure the diameter of this disc by means of a Berthon Dynamometer (see p.43) placed against the eye-piece—a pocket lens, of low power, should be used as an aid in doing this. The magnifying power of the eye-piece is found by dividing the clear diameter of the object glass by the measured diameter of the bright image.

Diameter of field.—To ascertain the diameter of the field of an eyepiece, observe how long a star situated

* This is on the assumption that the distance apart of the lenses is equal to half the sum of their focal lengths. I am indebted to the Rev. W. F. A. Ellison for pointing out that in the case of many eye-pieces this distance is not kept to by the opticians, and that the correct formula for all combinations is:—Focal length = $\frac{f_1 \times f_2}{f_1 + f_2 - d}$, where f_1 and f_2 are the focal lengths of the lenses and d their distance apart.

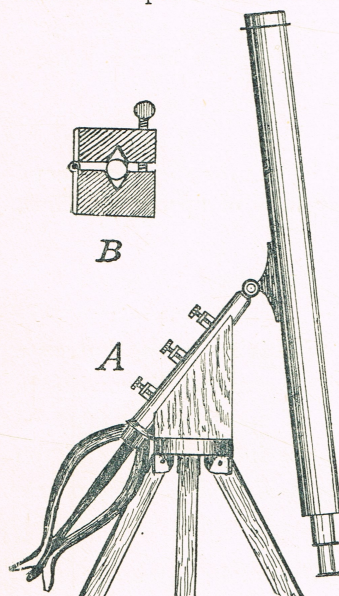
near the equator (e.g. δ ORIONIS) takes to pass centrally across the field from one side to the other. This time, expressed in minutes and seconds, when multiplied by 15, will give the diameter of the field in minutes and seconds of arc.

TESTS.

The actual performance of a telescope on a celestial object is the only really satisfactory test. Seen through a telescope bearing its highest power, a fixed star of the second magnitude should appear as a minute, well-defined, circular disc of light, almost a point, and surrounded by one or two thin, concentric, bright rings. There should be no false rays of light, and the rest of the field should be uniformly dark. The telescope should not, however, be condemned too hastily, as an inferior eye-piece, or the state of the air (see p. 33), may be responsible for apparent defects in the object glass. A close double star with very unequal components forms a most severe test. A telescope of the finest quality should separate a double, consisting of two 6th magnitude stars, whose distance from centre to centre in seconds of arc is equal to 4.56 divided by the aperture expressed in inches. (see Table p. 40).

ACCESSORIES.

Stands.—Much depends upon the rigidity of the telescope stand, and good observations must not be expected from the open window of an ordinary room, as the vibration of the floor, and the mixed currents of air, set the object being viewed dancing. For small telescopes, the ordinary, alt-azimuth, tripod garden stand is most convenient. An iron pipe of about 4 inches diameter, partly sunk in the ground, and rammed full of clay to deaden vibration, forms a good support for a telescope of moderate size.



The "equatorial" stand is of enormous advantage, but is rather expensive. It has one of the pivots, or axes, which carries the telescope, directed towards the celestial pole, (being adjustable for latitude). The result is that a star may be followed by a single circular movement of the telescope, instead of the instrument having to be moved both in altitude and azimuth. A make-shift is to screw to the stand top a wooden block cut off at an angle, as shown in the illustration (A), and which has a V-groove, with sides at an angle of 60° , cut along the inclined face, for receiving the pillar. The claw legs of the stand, folded up, will act as a counterpoise, and two or three screw clamps will keep the pillar firm. A piece of hard wood (not shown in the illustration), also V-grooved, should be interposed between the point of the screws and the pillar, to prevent damage when tightening up the screws. A somewhat simpler construction is to hinge this upper block at one side to the lower block, and pass the screws through both blocks at the other side, as shown in the illustration at (B).

The angle of the sloping top, from the vertical, must be the latitude of the observer subtracted from 90° . Thus, for latitude 52° it will be $90^\circ - 52^\circ = 38^\circ$.

Finder.—A finder is a small telescope fixed by supports to the body of the larger instrument. When high powers are used, this adjunct is a necessity, and in all cases it adds much to the comfort of observing. The finder may be roughly adjusted by day on a distant weather-cock or some other definite object. To improve the adjustment, bring the polar star into the centre of the field of a low power eye-piece on the large telescope; then alter the direction of the finder, by means of the adjusting screws, until the star image is in the centre of the field of the telescope, and also bisected by the cross wires of the finder at the same moment. Now replace the low-power eye-piece by one of high power, and perfect the adjustments in the same way. For small telescopes up to 3-inch, 'sights' similar to those on rifles can be arranged (painted white), which will be found of some service.

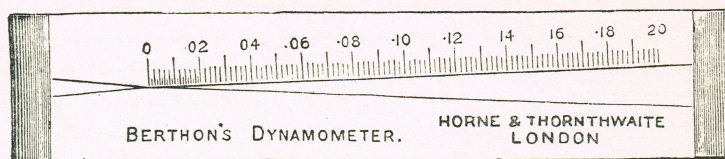
Dew-cap.—To guard against the deposition of dew on the object glass, make a tube of tin, cardboard, or some such material, about 9 inches or 1 foot long, and of such a diameter as to fit closely, but not too tightly, on to the object glass end of the tube. The inside of the dew-cap should be covered with black velvet, or painted with a mixture of lamp-black and size. Black blotting paper is also suitable.

Barlow Lens.—An achromatic concave lens fixed in an adapter and placed in the eye-end of the tube between the object-glass and the eyepiece, and about four or five inches in front of the latter. Its effect is equivalent to a lengthening of the focus of the instrument,* and thus it increases the magnifying power of any eyepiece: it also flattens the field of view.

Star Diagonal.—An L-shaped tube containing a right-angled totally-reflecting prism. One end of the fitting screws into the focussing-tube of the refractor, while the other end is screwed to receive an ordinary eyepiece. Its use prevents awkward positions of the body when viewing objects at high altitudes, but results in some loss of light and definition. A special diagonal is made for the Sun, which only requires a light shade glass (see note on p. 45).

* By half as much again, as usually constructed.

Berthon's Dynamometer (or measuring gauge) is a little instrument used for measuring the diameters of small objects. It has two flat metal sides, the internal straight edges of which meet towards the end, and are inclined to each other at a small angle. One of the edges is graduated from 0 to $\frac{2}{10}$ of an inch. The figures on the scale denote the width of the gap between the two straight edges. To measure the diameter of any small object by means of this little appliance, it is only necessary to see at what part of the scale the object *just* fills the space between the internal edges of the gauge, and then take the reading from the scale. The scale is divided into 20 long divisions of $\cdot 01$ or 1/100ths of an inch. These are subdivided into five parts, each equal to $\cdot 002$ or 1/500ths of an inch. The first two long divisions are again divided into parts equal to $\cdot 001$ or 1/1000ths of an inch.



Telescope House.—A tall folding clothes-horse, with a sheet fixed to it, and stayed by tent-ropes, forms a fair substitute, which will, to some extent, shield the telescope from vibration by the wind, and add to the observer's comfort.

TO CONSTRUCT A SIMPLE EQUATORIAL OR ALT-AZIMUTH STAND.

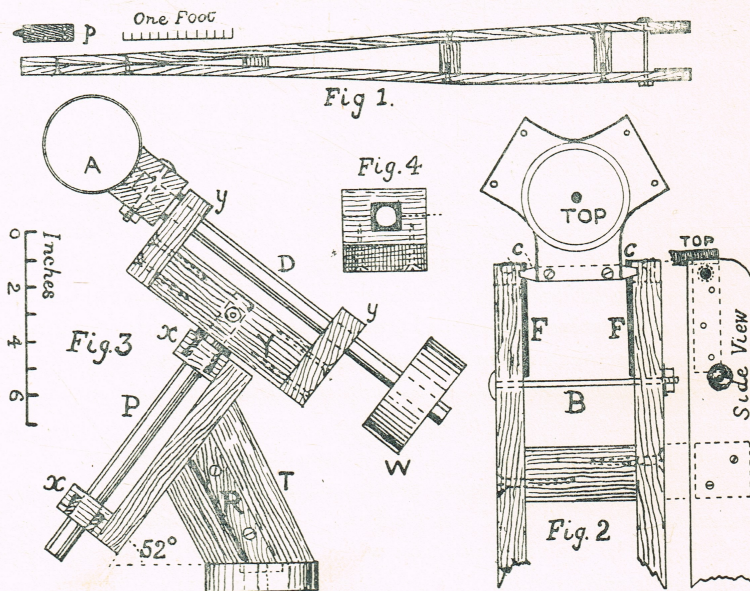
By following the directions and studying the diagrams given, any handy amateur, with the aid of a few simple tools, will be able at a very low cost to construct an efficient equatorial or alt-azimuth stand for a 3-inch or smaller refracting telescope. If made on a larger scale and of considerably thicker materials, the equatorial head here described, mounted on short, strong, fixed legs, would do equally well for a reflecting telescope of moderate size.

The Legs.—Take 3 deal boards about 6 to 6½ feet long, 5 inches wide, and 1 inch thick. Mark a point 2 inches from an edge at one end of the board and another point 3 inches from the same edge at the other end. Join the points found with a straight line and saw along it. This will divide the board into two equal flat pieces, each 1 inch thick, and tapering from 3 to 2 inches in width. These two pieces are joined together at distances of 1 inch and 9 inches from the narrow bottom end by 1½-inch screws (No. 9 or No. 10, about $\frac{3}{16}$ inch diameter). The two laths are kept apart by blocks of hardwood cut from a piece having a 2 inch square section, and held in place by screws. Thus the leg is formed as shown in Fig. 1, which is on a scale three times less than that of Figs. 2, 3 and 4. The laths should not be screwed together until the brass plates mentioned later on have been fitted. A metal plate (*p*) sawn or filed to a blunt point, may be screwed to the *inner* side of the foot, with the point projecting.

The Top of the Stand.—This is best made from an iron casting, for which a wooden pattern will be required. The pattern is made of $\frac{1}{4}$ -inch mahogany fretwood, cut to the shape shewn in Fig. 2, and strengthened by having a 4-inch bevelled disc of the same material glued and screwed on to it, so that the central part is $\frac{1}{2}$ inch thick. Each of the three projecting parts of the casting is either drilled with two $\frac{1}{4}$ -inch holes, each $\frac{1}{4}$ -inch distant from the 3-inch edge, to receive $\frac{1}{4}$ -inch bolts, or, as an alternative, $\frac{3}{16}$ -inch holes may be drilled, and tapped $\frac{1}{4}$ -inch Whitworth to receive metal screws. A $\frac{3}{8}$ -inch hole is drilled through the exact centre of the disc. Instead of the casting, a piece of tough, hardwood, such as beech, cut to the same shape, but at least 1¼-inches thick, may be used.

The Leg Pivots.—Cut a 12-inch length of $\frac{1}{2}$ -inch square brass bar into three equal pieces. In a lathe, turn half-an-inch at each end into a blunted cone (C, Fig. 2), the small outer end being $\frac{3}{8}$ -inch in diameter. If no lathe, file the ends to the same shape as carefully as possible. These bars are now drilled with $\frac{1}{4}$ -inch holes to correspond to the holes in the top, and are then screwed or bolted to the underside of the iron top.

The Hinge Plates.—To the top inner side, and towards the back of each of the laths forming the legs, is firmly screwed a flat, brass plate, 4 inches long, 1 inch wide and $\frac{3}{16}$ -inch thick (Fig. 2, F, and side view). The plate is flush with the top of the leg, which is rounded off at the outer top corner, and has in it near the top a $\frac{3}{8}$ -inch hole slightly enlarged, and coned to fit over the conical pins at C. B is a $\frac{1}{4}$ -inch bolt 6½ inches long, having a nut, bearing on a washer, which nut on being screwed up makes the hinge firm, and adjustable for wear.



The Equatorial Head (Fig. 3).—For this some pieces of oak or strong hardwood a full inch thick are required. The base is circular, and has, centrally fixed by screws in a recess in the bottom, a plate with a $\frac{3}{8}$ -inch Whitworth tapped hole, to receive a screw which clamps the head to the stand. This plate might be fixed in a recess on the upper side of the round base before the angle piece next referred to is fixed in position.

Fixed to the base is the trapezoid or angle piece of 1-inch wood (T). Strong glue and $2\frac{1}{2}$ -inch No. 12 screws should be used for fixing the parts. The top of this piece must be cut off at such a slope that the angle which it makes with the base is equal to the latitude of the place where the stand is to be used. A piece of wood 8 in. $\times$ 3 in. $\times$ 1 in. is screwed to the top of the trapezoid piece, and the whole is strengthened by adding the side pieces (R) which are 1 inch square.

The Polar Axis (P) is made of bright mild steel round rod, $\frac{3}{4}$ -inch in diameter and $11\frac{1}{2}$ inches long. This steel is easily obtainable at large tool and material stores. The upper end of the polar axis (P) is driven into a rather smaller hole in the block (Y) which is of hardwood 6 inches long by 2 inches square. Care must be taken to make this hole at right angles to the block. A $\frac{1}{4}$ -inch hole is drilled through block and axis, and a bolt inserted.

The Bearings (x, x) may be simply holes ($\frac{3}{4}$ -inch) in the hardwood blocks, with a simple split arrangement for taking up wear; but it is more satisfactory to enlarge and square (slightly undercutting) the greater part of each hole, and, with the axis in place, to pour in melted tin or pipe composition (lead and tin) to form more durable bearings. Before pouring the lead, coat the axis with a mixture of black lead and water and allow it to dry. If, when all is cold, the axis cannot be twisted round, when oiled, it should be *gently* hammered endways with a mallet. If there is still trouble, cut with an old saw along the dotted line (Fig. 4), through wood and bearing-metal down to the axis. The upper halves of the split bearings can then be held in place by screws. Similarly for the bearings (y, y).

The Declination Axis (D), another $\frac{3}{4}$ inch steel rod, about 14 inches long, is fixed, like the polar axis, at right angles in an 8 inches long, 2 inches square block, grooved for its whole length on one side to receive the telescope main tube (A). The telescope is fixed to the block by means of leather straps or thin metal bands. Thin $\frac{3}{4}$ -inch metal washers are placed between the blocks and the upper bearings of both axes. The balance-weight or counterpoise (w) is formed of a small round tin filled with lead, in which a piece of tube that just slides over the axis has been centrally fixed before the molten lead is poured in. The weight is so adjusted that it will counteract any tendency of the telescope to swing round by its own weight on the polar axis. It would be quite possible to fit graduated circles to this simple head. Celluloid circles can be obtained cheaply, and could be mounted on wooden discs of the same size—an addition which, with a carefully adjusted stand, will make possible the finding of Mercury and Venus in bright daylight and of stars by night from the places given in catalogues. But, even without circles, the advantage of being able to watch a star by only one movement will be found to be a great one.

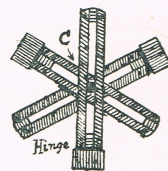
Alt-azimuth Head.—For this only the parts A, D, Y, W (Fig. 3) are required. The polar axis P is replaced by a $\frac{3}{8}$ -inch bolt which passes vertically and without shake through the central hole in the metal top of the tripod. A flat brass plate is screwed to, and protects from wear, the lower side of the block Y, which rests horizontally upon, and can be turned in azimuth about, the metal top. Turn or scrape the top flat, and grease with vaseline.

Adjusting the Equatorial Stand.—The completed stand is set up so that the top of the stand is level, with one of the legs of the tripod placed towards the south, and with the legs set well apart. Three strong cords of equal length should be made taut, one end of each to a central ring and the other end to a screw ring, fixed in the central cross-piece of each leg; this is a precaution against a possible accident.

The telescope tube is next set as nearly as possible parallel to the polar axis, and then, having slightly loosened the clamping screw, it will be sufficient, if no graduated circles are used, to gradually turn the equatorial head till (in the Northern Hemisphere) the Pole Star is seen in the field of view. The head is then clamped. Any slight adjustment in latitude required may be made by moving the southern leg of the tripod either inwards or outwards.

An alternative to the cords, which also renders the stand more rigid, is the addition of three stretcher bars, each made of two parallel metal strips, fixed $\frac{3}{8}$ -inch apart, and riveted to a short cross-piece at one end, and to the flap of a firm hinge at the other. The other hinge-flap is screwed to the central cross-piece of the leg, as shown in the illustration. A $\frac{3}{8}$ -inch bolt with a wing nut (c) passes through the three slots, and clamps the bars together.

When graduated circles are fitted, a more accurate adjustment of the equatorial head is necessary, if it is to be of practical use. With a movable stand it is well to have some means of replacing it in the same position when once it has been carefully adjusted, or much valuable time may be lost in re-adjusting it each night. Three stone slabs, or concrete blocks, having central gun-metal or brass plugs inserted, are set in the ground at the corners of an equilateral triangle equal in size to the most convenient leg base. Each metal plug has a hole or recess in the top, in which rests the previously-mentioned metal spike attached to the lower end of the leg. The adjustment of the head proper may be effected by means of thin wedges under the head, or, better, by three screws passing through the metal top of the tripod and bearing on the under side of the base of the head, which should be protected by a circular metal plate that rests on the points of the adjusting screws.



The true N. pole, towards which the polar axis should be directed as nearly as possible, lies about 1° (two Moon breadths) distant from Polaris, and very nearly on the straight line joining Polaris and η Ursæ Majoris—the last star in the tail of the Great Bear. If the time is chosen when the Pole star transits above or below the pole (see *N.A.*), and the telescope (set as before, parallel to the polar axis) is directed towards the Pole star, so that it appears in the centre of the field of view, then a lowering or a raising of the axis through 1° , by means of the southern adjusting screw, will make the adjustment sufficiently accurate for finding an object when using an eye-piece of low power.

HINTS ON CLEANING.

Refracting Telescope.—A good object glass is so delicately figured that it should be cleaned as rarely and carefully as possible, for fear of affecting the accuracy of its form. (*See below, "Cleaning."*)

The lenses should never be taken out of their cell by an inexperienced person.

The object glass should be held in its cell with just sufficient "play" for a slight rattle to be heard when it is gently shaken. If screwed up tightly, it causes strains in the glass which mar the perfect definition.

Reflecting Telescope.—The silvered mirror requires to be kept with very special care, as the silver is exceedingly liable to tarnish, especially in or near large towns, from the sulphurous fumes in the air. The owner of a reflecting telescope should, therefore, procure and study the "Hints on Reflectors," which have been published by several of the leading makers of these instruments.

A slight stain causes merely an inconsiderable loss of light, but, if badly tarnished, the mirror must be re-silvered. This process may be successfully accomplished by the amateur, with little difficulty, and at no great expense, if he carefully follows the directions given in the books just referred to, and uses pure chemicals.

Care of the Telescope.—Before removing the telescope after the night's work, cover the object glass or mirror with the metal cap provided for that purpose.

Never take the instrument from the cold outer air into a warm room, or the object glass will become dewed. If this should happen, the object glass must not be left in that state; but it should be placed in a warm room, at a safe distance from a fire, until the moisture has vanished. Any stains left on the glass must be removed by gentle polishing. Never wipe an object glass when it is damp.

Cleaning the Lenses.—When it becomes necessary to clean these, any dust should first be removed by means of a *camel's-hair brush*. Then the lens should be wiped very gently with a piece of very fine and clean wash-leather or silk.

When not in use, all brushes and materials employed for this purpose should be carefully protected from dust by keeping them in clean stoppered bottles or air-tight cases.

Solar Eye-pieces.—The use of a silvered or deeply-coloured Barlow lens with an ordinary eye-piece is a simple and effective way of reducing the Sun's light and heat. The chief objection to the silvered lens is that the film is so easily scratched. A special solar diagonal (Sir J. Herschel's), in which only about $\frac{1}{20}$ th of the Sun's light is reflected from the first surface of a narrow-prism, is procurable. With this, the addition of a light shade-glass is necessary. See illustration in Proctor's *Half-Hours with the Telescope*, new edn.

Helioscopes, or Helioscope eye-pieces, depending upon polarization, reduce the Sun's light sufficiently to enable a dark-glass to be dispensed with, but they are somewhat complicated and expensive appliances.

Spectroscopes.—Small instruments for viewing stellar spectra can be had at a comparatively low price; these screw on to or fit in the eye-piece tube. Those for viewing prominences, however, are much more expensive, as the dispersion required is considerable, and prices are of the order of £7 (\$35) upwards. It would be a great boon to amateur astronomers if some enterprising optician could bring out a satisfactory instrument for half that sum, or less.

Astronomical Photography.—Anyone possessing an equatorial telescope with a slow worm-wheel motion on the polar axis, can take good stellar (or cometary) negatives in a box camera attached to the tube of the telescope, using ordinary photographic lenses of $f/6$ or greater aperture, which should be carefully focussed by trial exposures; a driving clock is not essential, though advantageous. The telescope serves as a 'guider,' a star being kept steadily on cross-wires in the eyepiece; these wires can easily be added to a positive eyepiece by anyone accustomed to use tools. Exposures are rather lengthy, from some twenty minutes upwards—to hours for faint stars—and require patience.

Most refractors are not very suitable for taking photographs of the Sun and Moon in the telescope itself, without an eyepiece, as they do not bring the actinic and visual rays to the same focus, and the sharpest position has to be found by trial and error. Reflectors are free from this disadvantage, also 'photo-visual' refractors; but the latter are expensive. The Moon can be taken by a fixed telescope, of ordinary focal length, in about $\frac{1}{4}$ -second, but the image is small—in a 3-inch, only $\frac{1}{3}$ -inch diameter.

Those desirous of taking up this pursuit should procure 'Astronomical Photography,' by Mr H. H. Waters, F.R.A.S.—a little book which gives all needed information on the subject of apparatus, adjustment, exposure, &c.

A Celestial Globe, adjustable for latitude, is useful for finding the direction and altitude of Mercury, or a comet, in twilight, also the path of the Zodiacal Light. The stars are reversed as regards left and right on the globe, because we view the star sphere from the inside, and the globe is viewed from the outside.

THE MOON

General Notes.—The Moon is the most interesting of all the heavenly bodies for a small telescope. In an opera-glass the dark portions visible to the naked eye are seen to be the smoother portions of the Moon's surface; the remainder of the surface is a mass of craters of every size, from some of which brilliant white streaks radiate for a great distance. The most striking views are obtainable when it is about its first or last quarter, when the lunar mountains near the *terminator* (or boundary between the bright and dark portions), cast long dark shadows which give a fine effect of contrast with the bright sun-lit parts. At the time of full Moon this contrast is lost, though the systems of *rays* or bright streaks are then most in evidence, and an interesting field of study is the total, or nearly total, disappearance of prominent objects (*e.g.*, Maginus) for 2 or 3 days before and after 'Full,' while others (notably the craters, properly so called, see p. 48) can still be located by reason of their being brighter than their surroundings. This disappearance is very noticeable in formations traversed by the rays or streaks, as in the S. W. portion of the Moon. A low power should be used at first, for a general view of the disc. (See note on 'Observing the Moon,' p. 34).

The Moon always presents the same side to the Earth, so that one side of the Moon is never seen at all. Owing, however, to what is termed the Moon's *libration*, or apparent swaying, due to the inclination of its axis to its orbit, and to other causes, we sometimes see a little more on one side or another, so that altogether about six-tenths of the surface is visible at one time or another. A full description of the Moon is quite beyond the scope of the present work, but the following paragraphs, together with the map, and further notes, p. 48, indicate the principal features. Consult Elger's and Neison's detailed accounts of our satellite, and Nasmyth and Carpenter's interesting book; Proctor's volume deals particularly with her orbital and other peculiarities. See also Pickering's Photographic Atlas.

Lunar *plains*, the darker and smoother portions of the surface, were supposed by the early telescopists to be *seas*—which they much resemble under very low powers—and were named accordingly. More perfect instruments, however, revealed that the supposed seas were simply vast plains, by no means level, or smooth, possibly once the bottom of lunar oceans.

Lunar *mountain ranges* and peaks are much higher in proportion to the moon's diameter than terrestrial ranges are to the earth's diameter, some of them attaining a height of about five miles. The most conspicuous range is *The Apennines*, in the northern hemisphere of the moon, which rises like a wall from the *Mare Imbrium*. It is about 600 miles long, and its highest peaks attain a height of $3\frac{1}{2}$ miles—the heights being found by measurements of their long sharp shadows, nearly 100 miles long.

Lunar *craters*, which are such a prominent feature in lunar landscapes, are of all sizes from a hundred and fifty miles in diameter downwards. Craters often have one or more conical peaks within the crater walls, of which *Tycho* and *Gassendi* are fine examples; the largest with a fairly level bottom, and often no central peak, and with lower bounding walls than the craters proper, are called *walled plains*, of which *Plato* is the best example. The interiors of the craters are usually lower than the surface outside, but sometimes the reverse is the case. Frequently an old crater will be seen that has been broken into by a later one.

Lunar *rills* are deep, winding, narrow valleys, resembling the bed of a dried up stream. Lunar *clefts* appear like cracks on the smoother portions of the surface. It is difficult to realise that these hairlike markings are sometimes fifty or a hundred miles long and up to $2\frac{1}{2}$ miles in width. The greater number of clefts are to be seen only in pretty powerful telescopes. *Faults* are closed cracks in the moon's surface, and are numerous. They are visible owing to the surface on one side of them being higher than that on the other.

Lunar *rays* are the bright streaks which radiate from some of the principal craters. Unlike other lunar features, they are best seen about the time of full moon. The finest system of rays radiates from the great crater *Tycho*, in the southern lunar hemisphere. The strangest feature of these rays is that they are everywhere on the same level as the rest of the surface, and traverse unbroken both crater walls, valleys, and seas. No fully satisfactory explanation of their nature has yet been given.

Position Angle of the Moon's Axis.—This sways some 25° on each side of the hour-circle every month, the extremes being when her R.A. is about 0 hrs. and 12 hrs., *i.e.*, when crossing the celestial equator: it is about zero when her R.A. is 6 hrs. and 18 hrs. The amount is given in the 'Moon's Physical Ephemeris' in the *Nautical Almanac*.

Objects near the Limb. Those near the N. lunar pole are best situated for observation when the Moon has its greatest south latitude (about 5°), and *vice versa* for the S. pole; those near the west limb, when the Moon's actual longitude is E. of (*i.e.*, greater than), and those near the east limb when it is W. of (*i.e.*, less than) the mean longitude. The dates when any object near the limb will be nearest the centre, and thus most favourably situated for observation, can be ascertained from the *Nautical Almanac*, by finding the times when the favourable libration in latitude (p. 47) is about 6° , and that in longitude about 7° : the Moon, however, may be below the horizon, or the phase unsuitable.

Effects of Libration. At each recurring phase, though the positions and lengths of the shadows themselves have not changed greatly (lunar 'seasonal' changes being small, owing to the small inclination of the lunar equator to the Ecliptic, $1\frac{1}{2}^\circ$), the Moon's latitude and longitude, &c., have altered. Libration has come into play, and we view the object and its shadow from a different position than formerly, the variation amounting at its maximum to over 20° , through the combined effect of the displacement in latitude and longitude. Except at rare intervals, therefore, we do not re-observe objects under anything like the same conditions. When viewing the Moon, it should also be remembered that it is only near the centre of the disc that we see objects in their true form and dimensions, as each object is more and more foreshortened the further it is away from the centre, and, on the limb, is seen only in profile.

The libration on any evening can be found from the *Nautical Almanac* in the 'Moon's Physical Ephemeris,' columns Earth's 'Selenographic Lat. and Long.' When the libration in longitude is +, the mean centre of the disc is displaced to the E., i.e., the Mare Crisium is furthest from the limb. When the libration is -, the mean centre is displaced to the W., and the Mare Crisium approaches the limb. Similarly, when the libration in latitude is +, the mean centre is displaced to the S., i.e., Plato is furthest from the limb, and *vice versa*, for -.

Best Altitude Conditions.—For any given age of the Moon, there is a certain date in the year about which more favourable altitude conditions obtain than at any other time, though it is modified to some extent by the Moon's changes in latitude. This is due to the fact that the Moon's average path coincides with the Ecliptic, so that on any given day, her altitude above an observer's horizon at culmination, will, on the average, be exactly the same as that of the Sun at noon on the date when he has similar R.A. The following Table indicates approximately the most favourable dates for observing the principal phases: (S. Hemisphere, transpose April, Oct.: and July, Jan.):—

N. Hemisphere:—	Moon 3-4 days old.	First Quarter.	Full.	Last Quarter.	25-26 days.
<i>Most Favourable</i>	End of April	Vernal Equinox	Winter Solstice	Autumnal Equinox	End of July
<i>Least</i> ,,	,, October	Autumnal ,,	Summer ,,	Vernal ,,	,, January

The Position of the Terminator on the Moon's equator, corresponding to various ages, can be approximately ascertained by means of the scale below the Map of the Moon on p. 49. It can be obtained more exactly from the 'Moon's Physical Ephemeris,' 'Sun's co-longitude' column, in the *Nautical Almanac* (in conjunction with a lunar chart having selenographic latitude and longitude lines), by using the following rule:—

Sun's Co-longitude. From:—

Position of Terminator.

0° to 90°, the figures in the Table give	the terminator's longitude E. of the central meridian (Sun rising).
90° to 180°, subtract the Sun's co-longit. from 180°: answer = ,, ,, ,, W. ,, ,, ,, (Sun setting).	
180° to 270°, subtract 180° from the Sun's co-longit. ,, = ,, ,, ,, E. ,, ,, ,, (Sun setting).	
270° to 360°, subtract the Sun's co-longit. from 360°. ,, = ,, ,, ,, W. ,, ,, ,, (Sun rising).	

Repetition of same Phase of illumination, near the same hour, may be expected in about 2 and 15 lunations, on the average, but there are variations—corresponding with the lengths of different lunations, which vary to and fro between $29\frac{1}{4}$ and $29\frac{3}{4}$ days. The mean lunation is just over $29\frac{1}{2}$ days, hence, on the average, in the second lunation similar phase falls in daylight; in the third, it is $1\frac{1}{2}$ hours later in the evening than the first, and so on. 1 mean lunation = $29^d 12^h 44^m$; 2 lunations, $59^d 11^h$; and 15 lunations, $442^d 23^h$. The mean interval from perigee to perigee, or mean anomalistic period is 27.55455 days, and does not recur at the same phase till after 14 lunations (about 1.13 yrs.), or about $1\frac{1}{2}$ months later in the following year, so that 'most favourable' conditions gradually disappear for a period.

Lunar Nomenclature. Lunar objects are generally referred to the *quadrant*, or quarter of the disc, in which they are found, numbered I to IV, as on the map. The principal formations have names of their own: other objects in the neighbourhood (also those *inside* or *on* a crater), not separately named, are denoted by the nearest crater name with a *Roman* letter added, for craters or depressions, or a *Greek* letter, for peaks or elevations—capitals denoting 'measured' points. Thus 'Aristoteles B' is quite different from 'Aristoteles,' being a small crater some 50 miles N. of the latter. Greek letters are also used for rills, in conjunction with the crater names.

Earthshine, popularly known as 'the Old Moon in the New Moon's arms,' is due to rays of light reflected from the Earth on the Moon's dark disc. It is stronger in the morning with Old Moon than in the evening with New Moon, and its variations are worth systematic study, as an index to the reflective power of the Earth's disc, which is lit up by the Sun. As the albedo of clouds is very high (p. 6), unusual brightness of Earthshine probably indicates that the sun-illuminated hemisphere of the Earth is much cloudier than usual, and *vice versa* when Earthshine is faint. Earthshine is best seen 3 to 5 days after New Moon in the spring, or before New Moon in the autumn, especially if the Moon is near perigee at the time, its brightness then being greatest. Earthshine is also known as 'lumi re cendr e,' or 'ashy light.'

A very narrow ring of silver-white light, quite distinct from Earthshine, and encircling the whole lunar disc, is occasionally visible for short periods when the Moon is within 2 or 3 days of New.

Lunar Mountains are of two classes: (a) ordinary mountains—chains and smaller ranges, hills, ridges, peaks, &c., and (b) 'craters,' conventionally so called, with hollow centre, and central peak, or peaks—though this is sometimes absent, as in Plato. Craters are sub-divided into several types, but as these merge into one another, authorities classify some craters differently. In these sub-divisions, 'crater' is used in a special sense, to denote the type which seems most nearly to correspond to terrestrial craters. The more important types are:—

Walled Plains (marked † in Index) diameter 40-150 miles, usually surrounded by a complex succession of walls.

Floor usually not much lower than the outside, and comparatively level; central mountain often absent.

Ring-Plains (unmarked in Index) form the majority of lunar craters, diameter 20-60 miles. More uniform and circular than walled plains; generally surrounded by a single principal wall. Outer slope is small, interior steep and usually terraced, floor nearly always much lower than the outside, and comparatively level.

Craters proper (‡ in index); diam. 4-12 miles, circular, outer slope steep: floor small, with volcanic cone; a characteristic feature is brightness, which often enables them to be specially distinguishable at 'Full.'

The deepest crater in the Moon (Neison) is Newton, with a rim 23,800 feet above the interior: in Wargentín, the floor is practically level with the top of the wall. For a few of the outstanding features of the Moon, see page 46, and below. For fuller details, refer to 'Webb,' Neison's or Elger's books on the Moon, and Goodacre's with large map.*

Lunar 'Seas,' Valleys, &c. The Sinus Iridum, with great bounding cliffs, rising in peaks over 16,000 ft. high, is one of the finest objects on the Moon: it is best seen when the Moon is 8 or 9 days old.

Of the *valleys*, the Great Alpine Valley is the most notable. Most *clefts* or *rills*, and *faults*, are not visible in small instruments, but the Cleft of Hyginus, and the rill of Ariadeus just W. of it, can be seen in a two-inch telescope. The 'Straight Wall,' 60 miles long and 900 feet high, is a little E. of Thebit. Pico is a solitary peak on the Mare Imbrium.

The Brightness of different parts of the Moon is an interesting study: it is valued in 'degrees,' ranging from 1°, the darkest—found in Grimaldi and Riccioli—up to 10°, found in Aristarchus, the brightest object in the Moon; Proclus is 8°. 0° is black shadow. The floor of Plato undergoes curious changes in brightness as the Sun's altitude increases.

The varying colours of the Seas may also be studied. The prevailing tint is grey, more or less dark, Mare Crisium being the darkest (1½°-3°), with a tinge of green. The brightest of the grey plains is Lacus Somniorum (3½°-4°); Palus Somnii, equally bright, is of a yellow-brown shade. The Mare Serenitatis, the centre of Mare Humorum, and part of the Sinus Iridum, have a dark greenish colour, and the Mare Crisium a lighter green; the Mare Frigoris is yellowish-green.

Centres of Principal Ray Systems. Aristarchus, Aristillus, Byrgius A, Copernicus, Euler, Kepler, Messier, Proclus, Timocharis, and Tycho. Euclides and Landsberg A are surrounded by a 'nimbus,' or bright patch.

The Mean Centre of the Moon, or intersection of lunar meridian 0° with the lunar equator, can always be readily found, as it is approximately the point equidistant from the three craters, Herschel, Schröter, and Triesnecker. The lunar equator is very nearly the line drawn through Rhæticus and Landsberg; lunar longitude 0°, a line drawn through the centre of Walter and the E. side of Aristillus. But see note at foot of Map of the Moon as to curved lines.

Index, Map of the Moon. The diameters, given in miles, are approximate, as authorities sometimes differ, owing to irregular shape, &c. The letters Bc, Bb, &c. indicate the square in which the object will be found. † ‡, see above.

	Diam.		Diam.		Diam.		Diam.		Diam.
Agrippa	Bc 27m	Clavius†	Ca 142m	Hell	Ca 18m	Messier†	Ab 9m	Santbech	Ab 46
Albatagnius†	Bb 64	Cleomedest	Ac 78	Hercules	Bd 46	Moretus†	Ca 78	Schickard†	Da 134
Alpetragius	Cb 27	Copernicus	Cc 56	Herschel	Cb 24	Mösting, & A	Cb 15	Schiller†	Ca 113
Alphonsus†	Cb 83	Crüger	Db 30	Hevel†	Dc 71			Schröter	Cc 25
Anaximander	Cd 39	Cyrrillus†	Bb 65	Hippalus†	Cb 38	Newton	Ca 143	Stadius	Cc 43
Apollonius	Ac 30			Hipparchus†	Bb 92	Otto Struve†	Dc 150	Stöfler†	Ba 150
Archimedes	Cc 50	Delambre	Bb 32	Hyginus & Cleft Bc	4				
Ariadæus	Bc 5	Delisle	Cc 16			Parry†	Cb 25	Taruntius	Ac 44
Aristarchus	Dc 28	Encke	Dc 20	Kepler	Dc 22	Petavius†	Ab 100	Thebit	Cb 32
Aristillus	Bd 34	Endymion†	Bd 78			Philoläus	Cd 46	Theophilus	Bb 64
Aristoteles	Bd 51	Eratosthenes	Cc 38	Lambert	Cc 18	Piazzi†	Da 90	Timocharis	Cc 23
Arzachel	Cb 66	Euclides†	Cb 7	Landsberg	Cb 28	Picard	Ac 21	Triesnecker	Bc 14
Atlas	Bd 55	Eudoxus	Bd 40	Langrenus†	Ab 90	Piccolomini	Bb 57	Tycho	Ca 54
Autolycus	Bd 23	Euler	Cc 19	Letronne	Db 50	Pico	Cd ..		
				Lindenau	Ba 35	Pitatus†	Cb 58	Vendelinus†	Ab 90
Bailly†	Ca 149	Fabricius	Ba 55	Linné†	Bc 2	Plato†	Cd 60	Vieta	Db 51
Bessel†	Bc 14	Flamsteed	Db 9	Longomontanus†	Ca 90	Plinius	Bc 32	Vitello	Db 28
Birt	Cb 9	Fracastorius†	Ab 60			Posidonius†	Bd 62	Vitruvius	Bc 19
Blancanus	Ca 51	Furnerius†	Aa 80	Macrobius	Ac 42	Proclus	Ac 18	Vlacq	Ba 57
Bullialdus	Cb 38	Gambart	Cc 16	Maginus†	Ca 100	Ptolemæus†	Cb 115		
Burg	Bd 28	Gassendi†	Db 55	Mairan	Dd 25	Purbach†	Cb 60	Walter†	Ba 100
Byrgius, & A	Db 40	Gausst†	Ad 111	Manilius	Bc 25			Wargentín	Da 54
		Godin	Bc 23	Marius	Dc 27	Reiner	Dc 21	Werner	Bb 45
Capella	Ab 30	Grimaldi†	Db 147	Maskelyne	Bc 19	Reinhold	Cc 31	Wilhelm I.†	Ca 46
Capuanus	Ca 34			Maurolycus†	Ba 150	Rhæticus	Bc 25	Wurzelbauer†	Ca 50
Cassini	Bd 36	Hainzelt†	Ca 55	Mersenius	Db 41	Riccioli†	Db 106		
Catharinat†	Bb 70	Helicon	Cd 13	Messala†	Ad 69	Römer	Ac 24	Zach	Ba 46

* Published 1932. † Walled Plains.

‡ Craters.

SKETCH MAP OF THE MOON. (As seen in an inverting Telescope)



SCALE SHOWING APPROXIMATE POSITION OF THE TERMINATOR ON THE MOON'S EQUATOR AT VARIOUS AGES.

Young Moon 0 1 d y 2 d y 3 4 5 6 7 (3) 8 9 10 11 12 13 14 d.
Age, dys.
Old Moon 15 16 17 18 19 20 21 22 (3) 23 24 25 26 27 28 29

In using this or any other Map of the Moon, it must be remembered that :—

- (a). Objects very near the limb in the Map may be completely out of sight or much foreshortened, owing to libration. The Mare Crisium and Grimaldi for instance, almost touch the edge at extreme libration.
- (b). The lunar equator, and parallels of latitude, which are straight on the Map, are only seen thus when the libration in latitude is 0° , i.e., when the lunar axis is in the position of mean libration; at other times these lines are seen as ellipses of greater or less curvature, curved southwards when the libration in latitude is +, and curved northwards when the libration in latitude is -.
- (c). Similarly the meridian of lunar longitude 0° is only seen as a straight line when the libration in longitude is 0° ; at other times it also is elliptical, convex W. or E. according as the Moon's libration is - or +.
- (d). The mean centre of the disc is only seen in the centre when the libration in longitude and latitude are each 0° . At other times it may be displaced up to $7^\circ 45'$ in longitude and $6^\circ 44'$ in latitude, or as the combined result $10^\circ 16'$. The Moon's libration in longitude is 0° about perigee and apogee, and her libration in latitude about 0° when she is crossing the Ecliptic.

When the Moon's libration in longitude is - , the region exposed to view is on the E. limb, & Mare Crisium is nearer the limb, than mean position.

When the Moon's libration in longitude is	+	"	"	"	W.	"	"	further from	"	"
When the Moon's libration in latitude is	-	"	"	"	S. limb, & Plato	"	"	is nearer the limb than mean position.	"	"
"	+	"	"	"	N.	"	"	further from	"	"

LUNAR MOUNTAINS, &c.

	Height, ft.		Height, ft.
Alps,	Bd 12,000	Doerfel Mts.	Ca 26,000
Alpine Valley	Bd ...	Hæmus Mt.	Bc 8,700
Altai Mts.	Bb 13,000	Leibnitz Mts.	Ba 30,000
Apennines	Cc 18,500	Pyrenees	Ab 12,000
Bradley, Mt.	Bc 13,600	Riphean Mts.	Cb 2,700
Caucasus	Bd 18,500	Taurus Mt.	Ad 10,000

LUNAR SEAS (OR 'MARIA'), &c.

Mare Australe ... Aa	Mare Nectaris ... Ab	Lacus Somniorum ... Bd
„ Crisium ... Ac	„ Nubium ... Cb	Palus Nebularum ... Bd
„ Fœcunditatis Ab	„ Serenitatis ... Bc	„ Somnii Ac
„ Frigoris ... Cd	„ Tranquillitatis Ac	Sinus Aestuum ... Cc
Humboldtianum Ad	„ Vaporum ... Bc	„ Iridum Cd
Humorum ... Db	Ocean. Procellarum Dc	„ Medii Cc
„ Imbrium ... Cd	Lacus Mortis ... Bd	„ Roris Dd

ADDENDA.

Interesting New Minor Planets.—After the Notes on the Planets had been printed, it was announced that two tiny minor planets had been discovered which approach much nearer the Earth than Eros (p. 27), and the following preliminary information was given.

The first, at present designated 1932 EA, or the *Delporte Planet*, is estimated as having a diameter of 3 miles at most. It approaches within about 10 million miles of the Earth—about three-quarters that of the least possible distance of Eros. Period about $2\frac{3}{4}$ years. Unlike any planet previously known, it may be in opposition twice in one year.

The second, designated 1932 HA, or the *Reinmuth Planet*, is still smaller, being only about a mile in diameter, but it is of special interest as its orbit actually comes within that of Venus, so that it may transit the Sun. It may approach within two million miles of the Earth. Period about $1\frac{3}{4}$ years.

Additional Catalogues, Maps, &c. (See also p. 39).

Double Stars, within 120° of the N. Pole, New General Catalogue, by R. G. Aitken. Practically an extension of *Burnham's General Catalogue* (p. 39). Positions of over 17,000 objects for epochs 1900 and 1950, and all measurements to end of 1926, 2 vols., 4to. No. 417, *Carnegie Institution Publications*, 1932.

Map of Mars, by M. E. M. Antoniadi, in four plates, 8vo., in *L'Astronomie*, 1930, p. 411. A beautiful map, from the same author's *La Planète Mars, 1659-1929*; 240 pp., 4to., Paris; a valuable summary.

General Catalogue of Radial Velocities of Stars, Nebulae and Clusters, by J. H. Moore; nearly 2000 objects. *Publications Lick Observatory*, Vol. 18, 1932.

Pronunciation of Constellation and Star Names.—The pronunciation of the accents is as follows:—

ā as in fate	ē as in we	i as in ice	ō as in go	ū as in unite	Note:—This list follows the so-called English method of pronunciation which is generally used for Latin and Greek proper names in English context.
ă „ fat	ĕ „ met	ī „ ill	ŏ „ odd	ŭ „ up	
ā „ arm	ē „ water	... ..	ô „ orb	û „ urn	
â „ sofa	... ..	... ..	ōō „ food	... ..	
... ..					

Constellations.—(See last page). For the genitives (*g.*) of names ending in *-us*, *-um*, change the *-us* or *-um* into *-i* (pronounced *i*), as *Lupus*, (*g.*) *Lupi*. Those ending in *a*: change the *a* into *æ* (pronounced *ē*), as *Mensa*, *Mensæ*.

ANDROMEDA, ăn-drôm'ē-dă
 ANTLIA, ănt'li-ă
 APUS, ă'pūs (*g.*, ă-pōd'is)
 AQUARIUS, ă-kwā'ri-ūs
 AQUILA, ăk'wi-lă
 ARA, ă'ră
 ARGO, ăr'gō (*g.*, ăr'gōōs)
 ARIES, ă'ri-ēz' (*g.*, ă-ri-ē-tis)
 AURIGA, ô-ri'gă
 BOÖTES, bō-ō'tēz (*g.*, -tis)
 CAELUM, sē'lūm
 CAMELOPARDUS, kă-mēl'ō-părd-ūs
 CANCER, kăn'sēr (*g.* kăn-kri)
 CANES VENATICI, kă'nēz vē-năt'i-si, or -ki
 (*g.* kă'nūm vē-năt'i-kō'rūm)
 CANIS MAJOR, kă'nīs mă'jēr (*g.*, mă-jō-ris)
 CANIS MINOR, kă'nīs mī'nēr (*g.*, mī-nō-ris)
 CAPRICORNUS, kăp'ri-kōr'nūs
 CARINA, kă-ri'nă
 CASSIOPEIA, kăs'i-ō-pē'yă
 CENTAURUS, sēn-tō'rūs
 CEPHEUS, sē'fūs or sē'fē-ūs
 CETUS, sē'tūs
 CHAMAELEON, kă-mē'lē-ūn (*g.*, -lē-ōn-tis)
 CIRCINUS, sūr'si-nūs
 COELUM, sē'lūm
 COLUMBA, kō-lūm'bă
 COMA BERENICES, kō'mă bē'r'ē-ni-sēz
 CORONA AUSTRALIS, kō-rō'nă ôs-tră'lis
 „ BOREALIS, „ bō'rē-ă'lis
 CORVUS, kōr'vūs

CRATER, kră'tēr (*g.*, krăt'ēr-is)
 CRUX, krüks (*g.*, krōōsis)
 CYGNUS, sig'nūs
 DELPHINUS, dēl-fī'nūs
 DORADO, dō-ră'dō (*g.*, -dōōs)
 DRACO, dră'kō (*g.*, dră-kō'nīs)
 EQUULEUS, ē-kwōō'lē-ūs
 ERIDANUS, ē-ri-dă-nūs
 FORNAX, fôr'năks (*g.*, fôr-nă-sis)
 GEMINI, jēm'i-ni (*g.*, -nō'rūm)
 GRUS, grūs (*g.*, grōō'is)
 HERCULES, hūr'kū-lēz (*g.*, -lis)
 HOROLOGIUM, hōr'ō-lō'jī-ūm
 HYDRA, hī'dră
 HYDRUS, hī'drūs
 INDUS, in'dūs
 LACERTA, lă-sēr'tă
 LEO, lē'ō (*g.*, lē-ō-nīs)
 LEO MINOR, lē'ō mī'nēr (*g.*, mī-nō'rīs)
 LEPUS, lē'pūs (*g.*, lēp'ōr-is)
 LIBRA, lī'bră
 LUPUS, lū'pūs
 LYNX, līnks (*g.*, -līn-cis)
 LYRA, lī'ră
 (MALUS, mă'lūs)
 MENSA, mēn'să
 MICROSCOPIUM, mī-krō-skō'pī-ūm
 MONOCEROS, mō-nōs'ēr-ōs (*g.*, -ēr-ō'tis)
 MUSCA, mūs'kă
 NORMA, nōr'mă
 OCTANS, ôk'tănz (*g.*, ôk-tăn'tis)

OPHIUCHUS, ôf-i-ū'kūs
 ORION, ô-ri'ōn (*g.*, ôr-i-ō'nīs)
 PAVO, pă'vō (*g.*, pă-vō'nīs)
 PEGASUS, pēg'ă-sūs
 PERSEUS, pūr'sūs or pūr'sē-ūs
 PHOENIX, fē'nīks (*g.*, fē-nī'cis)
 PICTOR, pik'tōr (*g.*, pik-tōr'is)
 PISCES, pis'ēz (*g.*, pis'i-ūm)
 PISCIS AUSTRALIS, pis'is ôs-tră'lis
 PUPPIS, pūp'is (*g.*, pūp'is)
 PYXIS, pik'sis (*g.*, pik'sis)
 RETICULUM, rē-tik'ū-lūm
 SAGITTA, să-jīt'ă
 SAGITTARIUS, săj-i-tă'ri-ūs
 SCORPIO, skōr'pī-ō (*g.*, -ō'nīs)
 SCORPIUS, skōr'pī-ūs (*g.*, skōr'pī-i)
 SCULPTOR, skūlp'tēr (*g.*, skūlp-tō'rīs)
 SCUTUM, skū'tūm
 SERPENS, sūr'pēnz (*g.*, sēr-pēn'tis)
 SEXTANS, sēks'tănz (*g.*, -tăn'tis)
 TAURUS, tō'rūs
 TELESCOPIUM, tēl'ē-skō'pī-ūm
 TOUCANUS, tōō-kă'nūs
 TRIANGULUM, trī-ăng'ū-lūm
 „ AUSTRALIS, „ ôs-tră'lē
 URSA MAJOR, ūr'să mă'jēr (*g.*, ūrsē mă-jō'rīs)
 URSA MINOR, ūr'să mī'nēr (*g.*, ūr'sē mī-vela, vē'lă (*g.*, vē-lō'rūm) [nō'rīs)
 VIRGO, vūr'gō (*g.*, vūr'jī-nīs)
 VOLANS, vō'lănz (*g.*, vō-lăn'tis)
 VULPECULA, vūl-pēk'ū-lă

Star Names and Clusters. (See last page but one).

Achernar, ă'kēr-năr
 Acrab, ăk'răb
 Adara, ăd-ă'ră
 Albireo, ăl-bī'rē-ō
 Alchiba, ăl-kī-bă
 Alcor, ăl-kōr'
 Alcyone, ăl-sī'ō-nē
 Aldebaran, ăl-dēb'ă-răn
 Alderamin, ăl-dē-ră'min
 Algeiba, ăl-jē'bă
 Algenib, ăl-gēn'ib
 Algol, ăl'gōl, ăl-gōl'
 Algorab, ăl-gō-răb'
 Alhena, ăl-hēn'ă
 Alioth, ăl'i-ōth
 Alkaid, ăl-kă'id
 Alkalurops, ăl-kă-lū'rōps
 Alkes, ăl-kēz'
 Almak, ăl-măk'
 Alnilam, ăl-nī-lăm'
 Alphard, ăl-fărd'
 Alphecca, ăl-fēk'ă
 Alpheratz, ăl-fēr-ăts
 Alphirk, ăl-fūr'k'
 Alrai, ăl-răi'
 Alruccabah, ăl-rōō-kă'bă
 Alshain, ăl-shă'in
 Altair, ăl-tă'ir
 Alwaid, ăl-wă'id
 Antares, ăn-tă'rēz
 Arcturus, ărk-tū'rūs
 Arided, ăr-i-ded'
 Arneb, ăr'nēb
 Asterope, ăs-tēr'ō-pē
 Atlas, ăt'lăs
 Azelfafage, ăz-ěl-fă'fă-jē
 Azimech, ăz-i-mēk'

Baten Kaitos, băt'n-kī'tōs
 Bellatrix, bē-lă'triks
 Benetnasch, bē-nēt'năsh
 Betelgeuse, bēt-ēl-gūz'
 Canopus, kă-nō'pūs
 Capella, kă-pēl'ă
 Caph, kăf
 Castor, kăs'tēr or kăs'tēr
 Cor Caroli, kōr kăr'ō-lī
 Cor Hydra, kōr hī'drē
 Cor Leonis, kōr lē-ō'nīs
 Cor Scorpionis, kōr skōr-pī-ō'nīs
 Cor Scorpii, kōr skōr'pī-i
 Cor Serpentis, kōr sēr-pēn'tis
 Cursa, kūr-să' [ō-lă
 Deneb, Denebola, dēn'ēb, dē-nēb'
 Deneb Algiedi, dēn'ēb ăl-jē'dī
 Deneb Kaitos Shemali, dēn'ēb
 kitōs shă-mă'lē
 Diphda, dif'dă
 Dubhe, dōōb'hē
 Electra, ē-lēk'tră
 Enif, ēn'if
 Errai, ăr-răi'
 Etamin, ēt-ă-mīn'
 Fom, fōm
 Fomalhaut, fō'măl-hôt, fō'măl-ō
 Gemma, jēm'ă
 Giedi, jē'dī
 Gomeisa, gō-mī'să
 Hamal, hăm'al
 Homam, hō-măm'
 Hyades, hī'ă-dēz
 Izar, ē-zăr'
 Kaitain, kītăin
 Kaus Australis, kôs ôs-tră'lis
 Keid, kă'id, kē'id

Kelb al Rai, kēlb-ăl-răi
 Kocab, kō'kăb
 Kornephoros, kōr-nēf'ō-rūs
 Kursa, kūr-să'
 Maia, mă'yă, mī-ă'
 Markab, măr'kăb
 Marsik, măr'sēk
 Mebsuta, mēb-sōō'tă
 Megrez, mē'grēz
 Mekab, mē'kăb
 Menkalinan, mēn-kăl-i-năn'
 Menkar, mēn'kăr
 Merak, mē'răk
 Merope, mēr'ō-pē
 Mesarthim, mēs-ăr-tīm'
 Mintaka, mīn'tă-kă
 Mira, mī'ră
 Mirac, mī'răk, mē'răk
 Mirfak, mīr'făk
 Mirzam, mīr'zăm
 Mizar, mī'zăr
 Muphrid, mōō'frīd
 Nath, năth'
 Nekkar, nēk-kăr'
 Okda, ôk'dă
 Phakt, făkt
 Pheoda, fēk'dă
 Pleiades, plī'ă-dēz, plē'ă-dēz
 Pleione, plī-ō'nē
 Polaris, pō-lă'rīs
 Pollux, pōl'ūks
 Praesepe, prē-sē'pē
 Prima Giedi, prī'mă jē'dī
 Procyon, prō'si-ōn
 Pulcherrima, pūl-kēr'i-mă
 Ras Algethi, răs ăl-jē-tē'

Ras Alhague, răs ăl-hă'gwē
 Rastaban, răs-tă-băn'
 Regulus, rēg'ū-lūs
 Rigel, rī-gēl, rī-jēl
 Rotanev, rō'tă-nēv
 Sadachbia, sād-ăk-bē'ă
 Saldmelik, sād-ăl-mēl'ik
 Saldsud, sād-ăl-sōō'd
 Secunda Giedi, sē-kūn'dă jē'dī
 Scheat, shē-ăt'
 Schedar, shēd'ăr
 Sheliak, shēl'ăk
 Sheratan, shēr-ăt-tăn'
 Sirius, sir'i-ūs
 Sirrah, sir'ă
 Skat, skăt
 Spica, spī'kă
 Sulaphat, sōō-lă-făt'
 Svalocin, svăl'ō-kīn'
 Talitha, tă-lē-tă
 Tarazed, tăr'ă-zēd
 Taygeta, tă-ij'ē-tă
 Thuban, thōō-băn'
 Unukalhay, ū-nūk'ăl-hă'
 Vega, vē'gă
 Vindematrix, vīn-dē-mī-ă'triks
 Wasat, wă'săt
 Yed, yēd
 Zaurak, zou'răk
 Zawijah, ză'vē-jă
 Zozca, Zosma, zōs'kă, zōs'mă
 Zuben el Genubi, zōō-bēn' ēl jē-nōō'bē
 „ el Hakrabi, ēl hă-kră'bē
 „ es Chamali, -ēs-shă-mă'lē
 Zubenesch zōō-bēn'ēsh

TELESCOPIC OBJECTS—MAPS 1 & 2.

DOUBLE STARS.

- η CASSIOPEIÆ. 0h. 44m. N. $57^{\circ} 25'$. A binary star. Period 328 years. Magnitudes 4 and $7\frac{1}{2}$. Distance $5\cdot7''$ (1903), $6\cdot4''$ (1915). Colours, yellow and pale red.
- σ CASSIOPEIÆ. 23h. 55m. N. $55^{\circ} 20'$. A double star. Magnitudes $5\frac{1}{2}$ and $7\frac{1}{2}$. Distance $3''$. A grand field with a low power.
- β CEPHEI. 21h. 27m. N. $70^{\circ} 15'$. A 3rd mag. star with a bluish 8th mag. *comes*, $14''$ distant.
- ξ CEPHEI. 22h. 2m. N. $64^{\circ} 15'$. A double star. Mags. of components 5 and $6\frac{1}{2}$. Distance about $7''$.
- δ CEPHEI. 22h. 26m. N. $58^{\circ} 0'$. A fine double star. The brighter star varies from $3\cdot7$ to 5 mag. in a period of 5d. $8\frac{3}{4}$ h. The companion is a 5th mag. blue star, $41''$ distant.
- ν DRACONIS. 17h. 30m. N. $55^{\circ} 15'$. A double star composed of two $4\frac{1}{2}$ mag. stars. Distance $62''$.
- ζ URSE MAJORIS (*Mizar*). 13h. 20m. N. $55^{\circ} 20'$. The middle star of the Great Bear's tail. A splendid double star with components of the 2nd and 4th magnitudes and $14''$ apart. It forms with 80 (*Alcor*), about $11'$ distant, a naked-eye pair. Several fainter stars are included in a large field.
- α URSE MINORIS (*Polaris*). 1h. 32m. N. $88^{\circ} 50'$. The North Polar Star. In 1920 about $1^{\circ} 7'$ from the north celestial pole, and in the year 2095 within $26' 30''$. It is a 2nd mag. star with a 9th mag. bluish attendant $19''$ distant, a well known test for instruments of less than 3 in. aperture. Polaris can easily be found by means of the "Pointers," α and β Ursæ Majoris.
- π^1 URSE MINORIS. 15h. 34m. N. $80^{\circ} 40'$. A double star, north preceding ζ . Components of the 6th and 7th mags. Distance $30''$.

VARIABLE STARS.

- μ CEPHEI. 21h. 41m. N. $58^{\circ} 25'$. An irregular variable star "of a fine deep garnet colour." (Sir W. Herschel).
- NOVA CASSIOPEIÆ. 0h. 20m. N. $63^{\circ} 40'$. The New Star of 1572 which equalled Venus in brilliancy and then died away. The place should be carefully watched for a possible reappearance.

NEBULÆ & STAR CLUSTERS. (*H.VI 30=7789; M.52=7654; H.IV.37=6543; M.97=3587*).

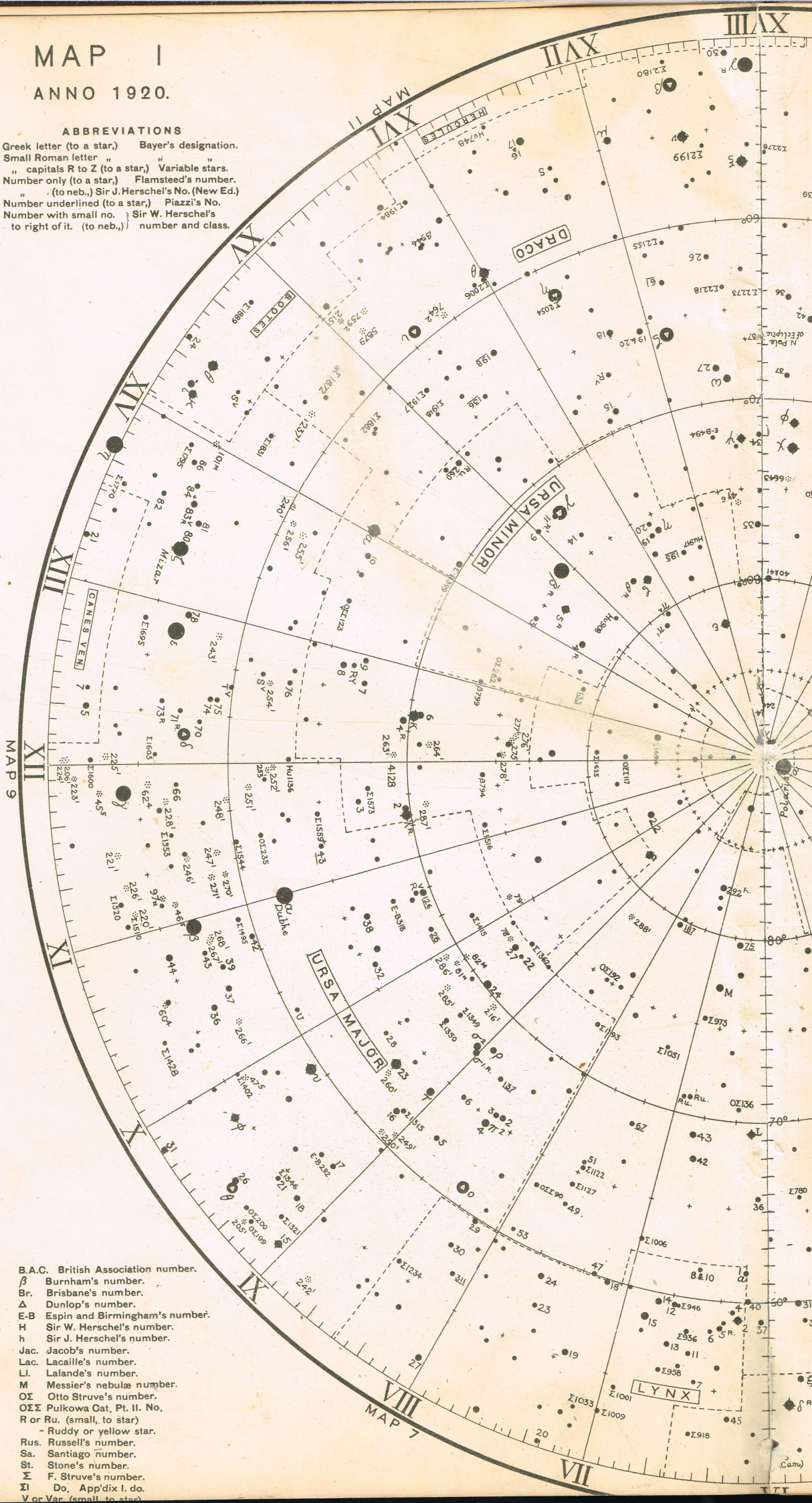
- H. VI. 30 CASSIOPEIÆ. 23h. 53m. N. $56^{\circ} 15'$. A beautiful cluster of small stars. Grand neighbouring fields.
- M. 52 CEPHEI. 23h. 21m. N. $61^{\circ} 10'$. An irregular cluster containing an orange-coloured star.
- H. IV. 37. DRACONIS. 17h. 59m. N. $66^{\circ} 35'$. A remarkable, bluish, elliptic, planetary nebula. It lies near the N. Pole of the Ecliptic, between the Polar Star and γ Draconis.
- M. 97. URSE MAJORIS. 11h. 10m. N. $55^{\circ} 30'$. A large, remarkable, planetary nebula with a faint disc, of the apparent diameter of Jupiter. The "Owl Nebula" of Lord Rosse: so called from its appearance in his great reflector.

ADDENDA:

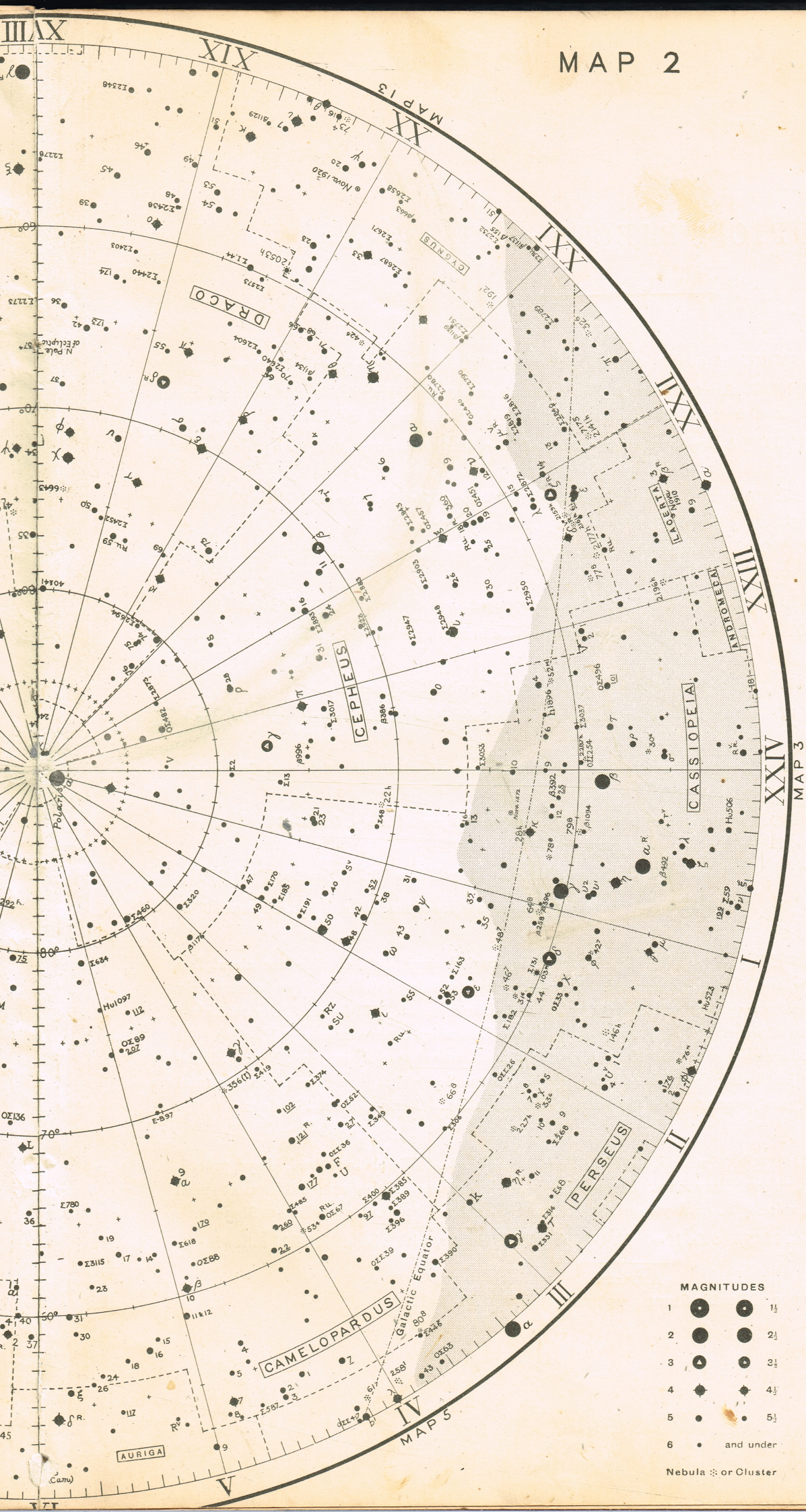
Distance of Double Stars. η Cassiopeiæ, $8''$ (1925); ξ Cephei, $6''\cdot95$.

MAPS 1 AND 2
(Circumpolar, North)

B.A.C. British Association number.
 β Burnham's number.
 Br. Brisbane's number.
 Δ Dunlop's number.
 E-B Espin and Birmingham's number.
 H Sir W. Herschel's number.
 h Sir J. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 Ll. Lalande's number.
 M Messier's nebula number.
 O Σ Otto Struve's number.
 O $\Sigma\Sigma$ Pulkowa Cat, Pt. II. No.
 R or Ru. (small, to star)
 - Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 Σ F. Struve's number.
 XI Do. App'dix I. do.
 V or Var. (small to star)



MAP 2



MAGNITUDES

1			1½
2			2½
3			3½
4			4½
5			5½
6			and under

Nebula ☼ or Cluster

TELESCOPIC OBJECTS—MAPS 3 & 4.

DOUBLE STARS.

- π ANDROMEDÆ. 0h. 32m. N. 33° 15'. A double star. Components of the 4th and 8th mags. Distance 36".
- γ ANDROMEDÆ. 1h. 59m. N. 41° 55'. A magnificent double star: an orange 3rd magnitude star with a blue 5th mag., 10" distant. The smaller star is a very close 55-yr. binary. 1891 almost closed, 1916 (widest), 0.65".
- 41 AQUARI. 22h. 10m. S. 21° 30'. A double star consisting of a reddish 6th. mag. star with a blue 8th mag., 5" distant.
- ζ AQUARI. 22h. 25m. S. 0° 25'. A very fine object in a small telescope. Its distance of 4.5" in 1780 had closed to 3" in 1892. 2.8" (1915). Magnitudes 4 and 4.1. A binary star.
- ψ^1 AQUARI. 23h. 12m. S. 9° 30'. A wide double star (50"). The brighter star is of mag. 4½, and yellow; the other 8½ mag., and blue.
- 8 LACERTÆ. 22h. 32m. N. 39° 10'. A quadruple star, whose components are of the mags. 6, 6½, 10 and 9.
- ϵ PEGASI. 21h. 40m. N. 9° 30'. A triple star, but only a wide double in small telescopes. Magnitudes 2½ and 9. Distance 140".
- π^1 PEGASI. 22h. 6m. N. 32° 45'. Forms with π^2 a fine wide pair. Magnitudes 5½ and 4.
- η PEGASI. 22h. 40m. N. 29° 45'. A 3rd mag. star with a 10th mag. companion, 90" distant. A test for a 3-inch telescope.
- 35 PISCUM. 0h. 11m. N. 8° 20'. A double star. The components are of about the 6th and 7th mags. Distance 11.5".
- ι TRIANGULI. 2h. 8m. N. 29° 55'. A lovely double star. Its components are of mags. 5 and 6½. Distance 3.6".
- α PISCUM. 1h. 58m. N. 2° 23'. A fine double star: pale green and blue. Mags. 2.8 and 3.9. Distance 2".43 (1921).
- ι TRIANGULI. 2h. 8m. N. 29° 55'. A lovely double star. Its components are of mags. 5 and 6½. Distance 3".6.

VARIABLE STAR.

- $\circ$ CETI (*Mira*). 2h. 15m. S. 3° 20'. A wonderful irregular 'long-period variable,' invisible for about five months without a telescope, and sinking to mag. 9.6. Thereafter it is visible to the naked eye for some six months, rising at maximum to mag. 5 or 4 (occasionally to the 3rd, and even to 1.7) for a week or two, after which it falls less quickly to minimum again. At maximum the total radiation of the star is only 1.7 times that at minimum, but the light increases some 1400 times, apparently from outbursts of hydrogen. Nearly all the radiation, at minimum, is just below the limit of visibility, thus a small percentage of increase in the total radiation, is, relatively, a great percentage on the small visible radiation. Period, about 330 days.

NEBULÆ & STAR CLUSTERS.

- M. 31 ANDROMEDÆ. (*N.G.C.* 224). 0h. 38m. N. 40° 50'. The Great Nebula. Visible to the naked eye, preceding ν . In small telescopes, an oval, hazy mass. Photographs show it as a wonderful spiral: unlike most spiral nebulae it is approaching; velocity 300 km. per second. Distance 935,000 light-years, according to Shapley.
- H. VIII. 75, LACERTÆ. (*N.G.C.* 7243). 22h. 12m. N. 49° 30'. A fine cluster, with a beautiful field following it.

ADDENDA:

Distance of Double Stars. γ ANDROMEDÆ: 0".56 (1921).

MAPS 3 AND 4
(R.A. XXII hrs. to 11 hrs.)

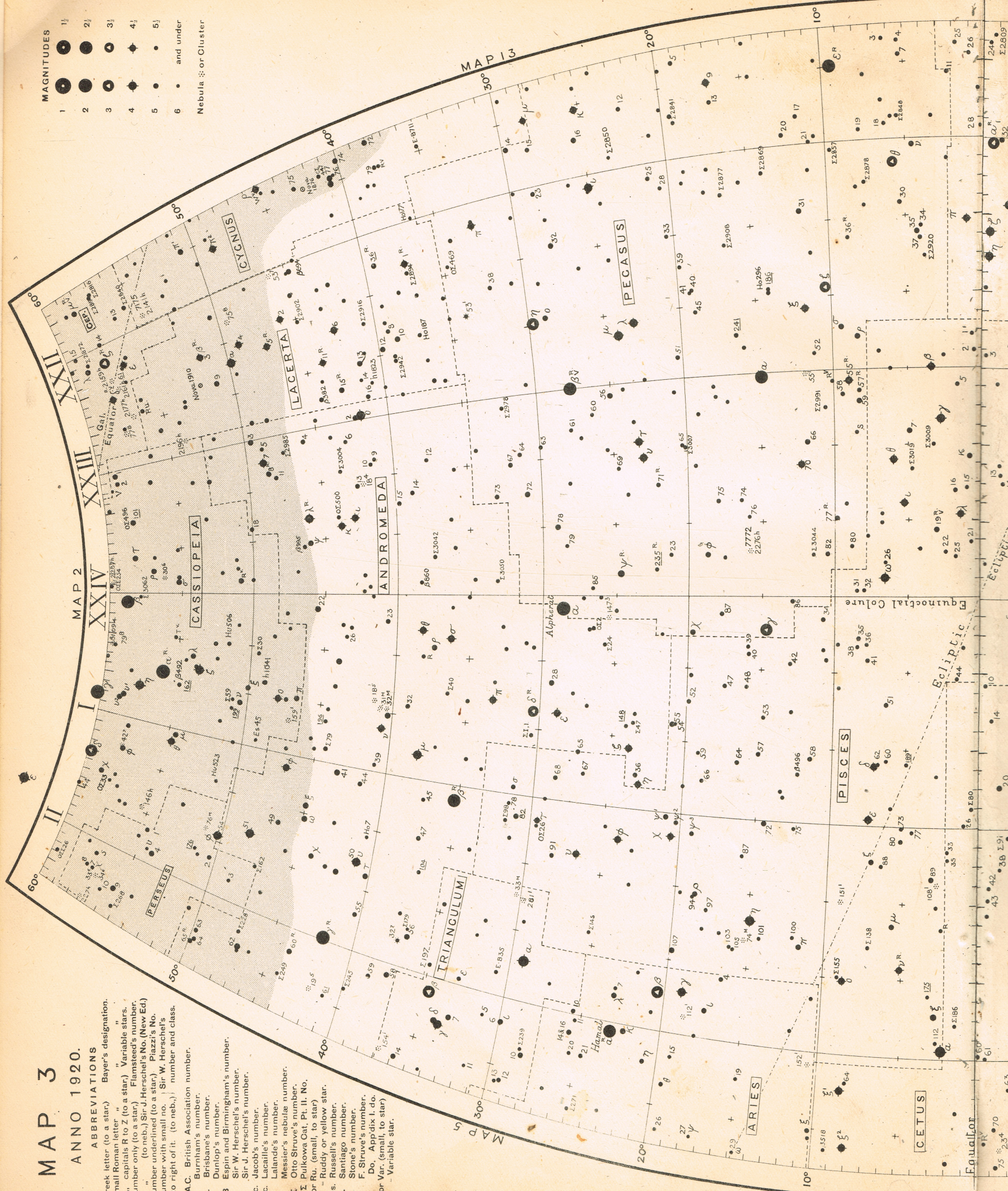
MAP 3

ANNO 1920.

ABBREVIATIONS

Greek letter (to a star) Bayer's designation.
 Small Roman letter " capitals R to Z (to a star) Variable stars.
 " " only (to a star) Flamsteed's number.
 " (to neb.) Sir J. Herschel's No. (New Ed.)
 Number underlined (to a star) Piazzi's No.
 Number with small no. Sir W. Herschel's
 to right of it. (to neb.) number and class.
 B.A.C. British Association number.
 β Burnham's number.
 Br. Brisbane's number.
 Δ Dunlop's number.
 E-B Espin and Birmingham's number.
 H Sir W. Herschel's number.
 h. Sir J. Herschel's number.
 Jac. Lacaille's number.
 L Lalande's number.
 M Messier's nebula number.
 OZ Otto Struve's number.
 OZZ Pulkowa Cat. Pl. II. No.
 R or Ru. (small, to star)
 Rus. Ruddy or yellow star.
 St. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 Σ F. Struve's number.
 Σ Do. Appendix I. do.
 V or Var. (small, to star) Variable star.

MAGNITUDES
 1 2 3 4 5 6 and under
 Nebula :: or Cluster



MAP 13

MAP 2

Equator

Equinoctial Colure

Ecliptic

TELESCOPIC OBJECTS—MAPS 5 & 6.

DOUBLE STARS.

- γ ARIETIS. 1h. 49m. N. $18^{\circ} 55'$. A double star discovered by Hooke in 1664. Magnitudes of each component, $4\frac{1}{2}$. Distance $8.6''$. A fine object.
- γ CETI. 2h. 39m. N. $2^{\circ} 50'$. A 3rd mag. yellowish star with a 7th mag. companion. Distance $2.6''$.
- 32 ERIDANI. 3h. 50m. S. $3^{\circ} 10'$. A double star. The brighter component is of the 4th mag., and yellow: the fainter 6th mag., and blue or green. Distance $6.7''$.
- γ LEPORIS. 5h. 41m. S. $22^{\circ} 30'$. A triple star. The chief components are of mags. 4 and $6\frac{1}{2}$, and $9.3''$ distant. A third faint star is $45''$ from the $6\frac{1}{2}$ mag.
- β ORIONIS (*Rigel*). 5h. 11m. S. $8^{\circ} 20'$. A star of the 1st mag. with a bluish 7th mag. attendant, $9.5''$ distant. Well seen in $2\frac{1}{4}$ -inch Wray.
- ϵ ORIONIS. 5h. 31m. S. $5^{\circ} 55'$. A double star. Magnitudes 3 and 7. Distance $11''$.
- σ ORIONIS. 5h. 34m. S. $2^{\circ} 40'$. A multiple star. The chief components are of the magnitudes 4, 10, $7\frac{1}{2}$, and 7.
- 52 ORIONIS. 5h. 44m. N. $6^{\circ} 25'$. A double star, consisting of two equal 6 mag. stars at $1.5''$ distance (1906). A hard test for 3 in.
- η PERSEI. 2h. 44m. N. $55^{\circ} 35'$. A yellow 4th mag. star, with a blue attendant of $8\frac{1}{2}$ mag. Distance $28''$.
- α TAURI (*Aldebaran*). 4h. 31m. N. $16^{\circ} 20'$. A star of the 1st mag. with an 11th mag. attendant, $109''$ distant. A good light-test for a 3 in. telescope.

VARIABLE STARS.

- β PERSEI (*Algol*). 3h. 3m. N. $40^{\circ} 40'$. The Demon Star. This notable variable has a period of 2d. 20h. 49m. Its usual magnitude for about $2\frac{1}{2}$ days is $2\frac{1}{2}$. In nearly $3\frac{1}{2}$ hrs. it decreases to 3.6 mag., and after remaining at that for 18 or 20 minutes, in another $3\frac{1}{2}$ hrs. it regains its former brilliancy.

NEBULÆ & STAR CLUSTERS. (N.G.C. Nos.:—M.38=1912; M.37=2099; M.42=1976; H. VI. 33.34=869, 884; M.1=1952.)

- M. 38. AURIGÆ. 5h. 23m. N. $35^{\circ} 45'$. A grand cluster in a splendid neighbourhood.
- M. 37. AURIGÆ. 5h. 47m. N. $32^{\circ} 30'$. An extremely beautiful cluster of about 500 stars.
- M. 42 ORIONIS. 5h. 31m. S. $5^{\circ} 27'$. "The Great Nebula in Orion," visible to the naked eye, is a fine object even in small telescopes. In its brightest part are four stars of 6, 7, $7\frac{1}{2}$, and 8 mags., which form the well-known "trapezium."* Two other stars have been glimpsed here in a 3-inch telescope.
- H. VI. 33, 34. 2h. 15m. N. $56^{\circ} 45'$. The Cluster in the Sword Handle of Perseus. Two magnificent clusters, in the same field with a low power.
- M. 1 TAURI. 5h. 30m. N. $22^{\circ} 0'$. This nebula was discovered in 1731, forgotten, and rediscovered by Messier in 1758. The discovery led him to make his catalogue of 103 nebulae. The "Crab Nebula" of Lord Rosse.
- THE PLEIADES. A beautiful naked-eye cluster of 6 or 7 stars, though some have made out 14, and even 16, without optical aid. *Alcyone* is the brightest star, 3rd mag. A very low power with a wide field should be used.

* Known as θ Orionis.

MAPS 5 AND 6

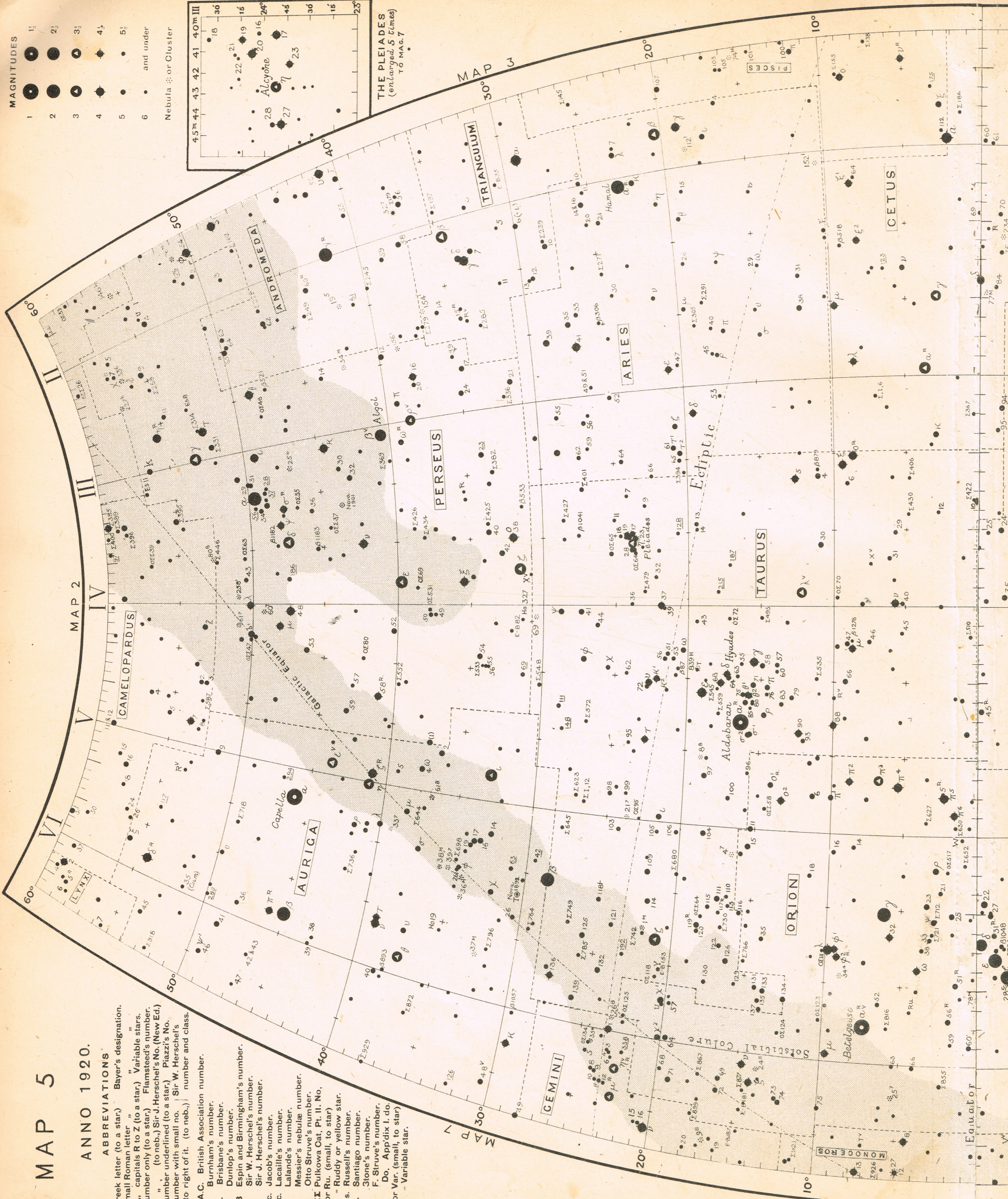
(R.A. II hrs. to VI hrs.)

MAP 5

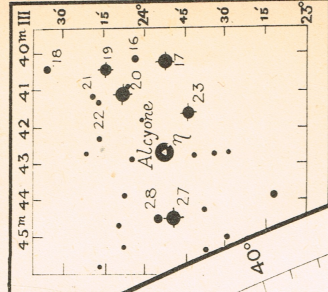
ANNO 1920.

ABBREVIATIONS

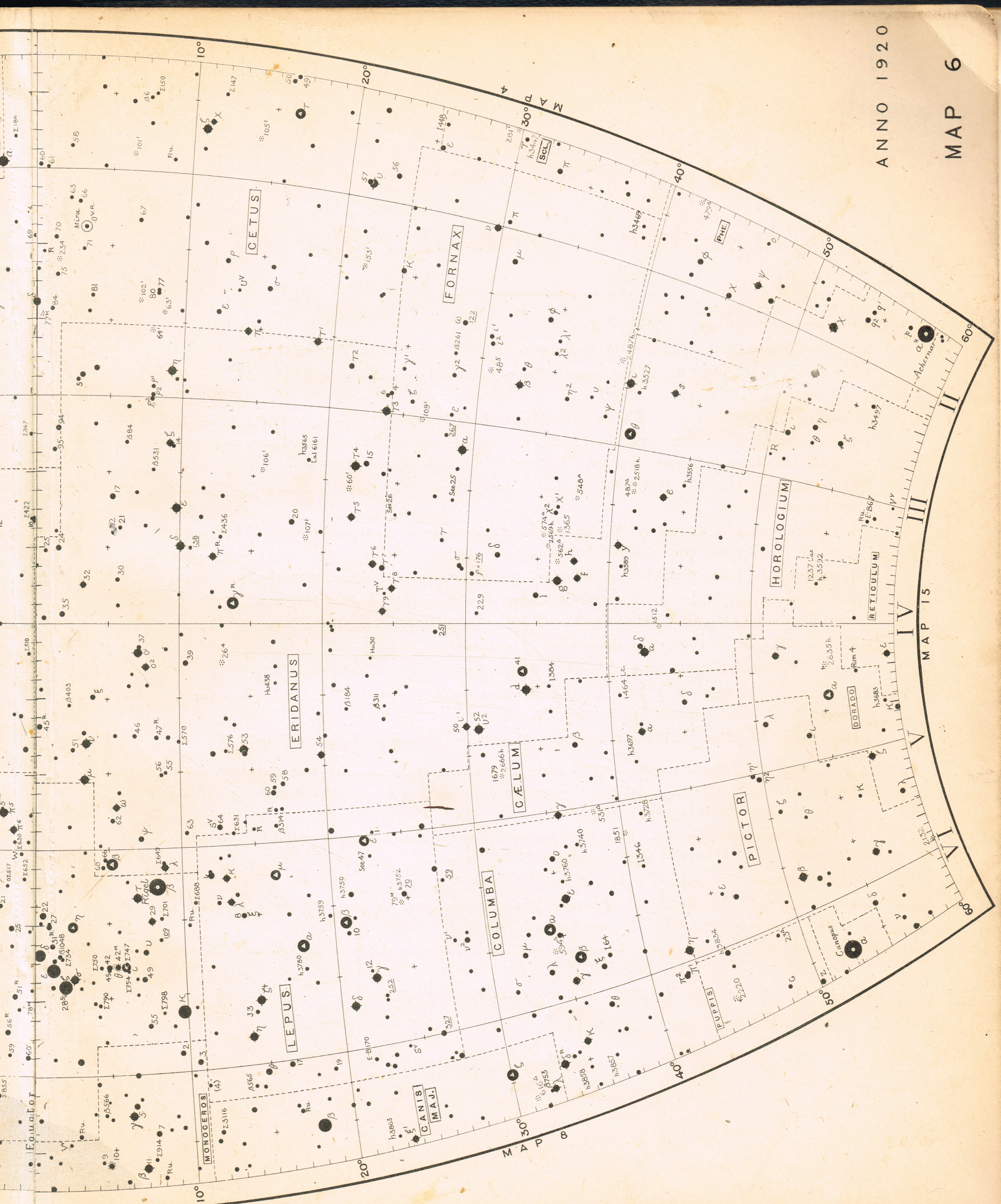
- Greek letter (to a star) Bayer's designation.
 Small Roman letter " " Variable stars.
 " capitals R to Z (to a star) Flamsteed's number.
 Number only (to a star) Sir J. Herschel's No. (New Ed.)
 " (to neb.) Sir J. Herschel's No. (New Ed.)
 Number underlined (to a star) Piazzi's No.
 Number with small no. | Sir W. Herschel's
 to right of it. (to neb.) number and class.
 B.A.C. British Association number.
 B Burnham's number.
 Br. Brisbane's number.
 D Dunlop's number.
 E-B Espin and Birmingham's number.
 H Sir W. Herschel's number.
 h Sir J. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 L.L. Lalander's number.
 M Messier's nebula number.
 O.S. Otto Struve's number.
 O.S. Pulkova Cat. Pl. II. No.
 R or Ru. (small, to star)
 - Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 S. F. Struve's number.
 Zl Do. Appendix I. do.
 V or Var. (small, to star)
 - Variable star.



- MAGNITUDES**
- 1 ●
 - 2 ●
 - 3 ●
 - 4 ●
 - 5 ●
 - 6 ● and under
- Nebula ☼ or Cluster



THE PLEIADES
(enlarged 5 times)
TO MAG. 7



ANNO 1920

MAP 6

TELESCOPIC OBJECTS—MAPS 7 & 8.

DOUBLE & MULTIPLE STARS.

- h 273. ARGÛS. 7h. 35m. S. $26^{\circ} 35'$. A double star. Two 4th mag. stars at a distance of $10''$.
- 5 ARGÛS. 7h. 44m. S. $12^{\circ} 0'$. A double star. The magnitudes of the components are $5\frac{1}{2}$ and $7\frac{1}{2}$, and their distance $3.3''$.
- ζ CANCRI. 8h. 7m. N. $17^{\circ} 50'$. A triple star. Magnitudes 5, $5\frac{1}{2}$ and $5\frac{1}{2}$. Distances $0''.61$ (1925) and $5''.5$.
- α CANIS MAJORIS (*Sirius*). 6h. 42m. S. $16^{\circ} 35'$. The brightest fixed star. Its 8.4 mag. companion is invisible in all but the largest telescopes. Distance $10''.8$ (1925). Period 49 years.
- μ CANIS MAJORIS. 6h. 52m. S. $13^{\circ} 55'$. A double star. Magnitudes 4.7 and 8. Dist. $2.3''$ (1901). Colours, yellow and blue.
- ζ GEMINORUM. 6h. 59m. N. $20^{\circ} 40'$. The components of this star are of the 4th and 7th mags. Distance $94''$. Two faint *comites* have been seen, one of them with a 3 in. telescope. (1925)].
- 8 GEMINORUM. 7h. 15m. N. $22^{\circ} 10'$. A yellowish 3rd mag. star, with an 8th mag. companion, $6''.7$ distant
- α GEMINORUM (*Castor*). 7h. 29m. N. $32^{\circ} 5'$. A binary star with a period of about 350 years. A splendid object in a small telescope. Magnitudes 2 and 2.8. Distance $5''.2$ (1914), $4''.55$ (1925).
- 17 HYDRÆ. 8h. 51m. S. $7^{\circ} 40'$. Two almost equal stars of about the 7th mag., $4.3''$ apart.
- 12 LYNCS. 6h. 39m. N. $59^{\circ} 30'$. A triple star. Magnitudes 5, 6 and $7\frac{1}{2}$. Distances $1.6''$ and $8.4''$.
- 8 MONOCEROTIS. 6h. 19m. N. $4^{\circ} 40'$. A double star in a grand low-power field. A yellow 4th mag. star, with a bluish *comes* of between the 6th and 7th mag.
- 11 MONOCEROTIS. 6h. 25m. S. $7^{\circ} 0'$. A triple star. Magnitudes 5, $5\frac{1}{2}$ and 6. Distances $7''$ and $2.5''$.

NEBULÆ & STAR CLUSTERS. N.C.G. Nos.:—H.IV.27=3242; H.VII.2=2244; M.50=2323; M.44=2632; M.67=2682; M.35= [2168.]

- H. IV. 27. HYDRÆ. 10h. 21m. S. $18^{\circ} 15'$. A planetary nebula south of μ. It is of a slightly elliptical shape, resembling Jupiter. It bears magnifying well.
- H. VII. 2. MONOCEROTIS. 6h. 28m. N. $4^{\circ} 55'$. A beautiful cluster, the brightest stars being of the 7th and 8th magnitudes. It includes the 6th mag. star 12 Monocerotis.
- M. 50 MONOCEROTIS. 6h. 59m. S. $8^{\circ} 11'$. A brilliant cluster.
- M. 44 CANCRI. 8h. 35m. N. $20^{\circ} 15'$. *Praesepe*. A naked-eye cluster. A large field and a low power are needed to see it properly. The 'Bee-hive Cluster.'
- M. 67 CANCRI. 8h. 47m. N. $12^{\circ} 5'$. A loose cluster of about 200 stars, chiefly of the 9th and 10th magnitudes.
- M. 35 GEMINORUM. 6h. 4m. N. $24^{\circ} 20'$. A glorious cluster, visible to the naked eye.

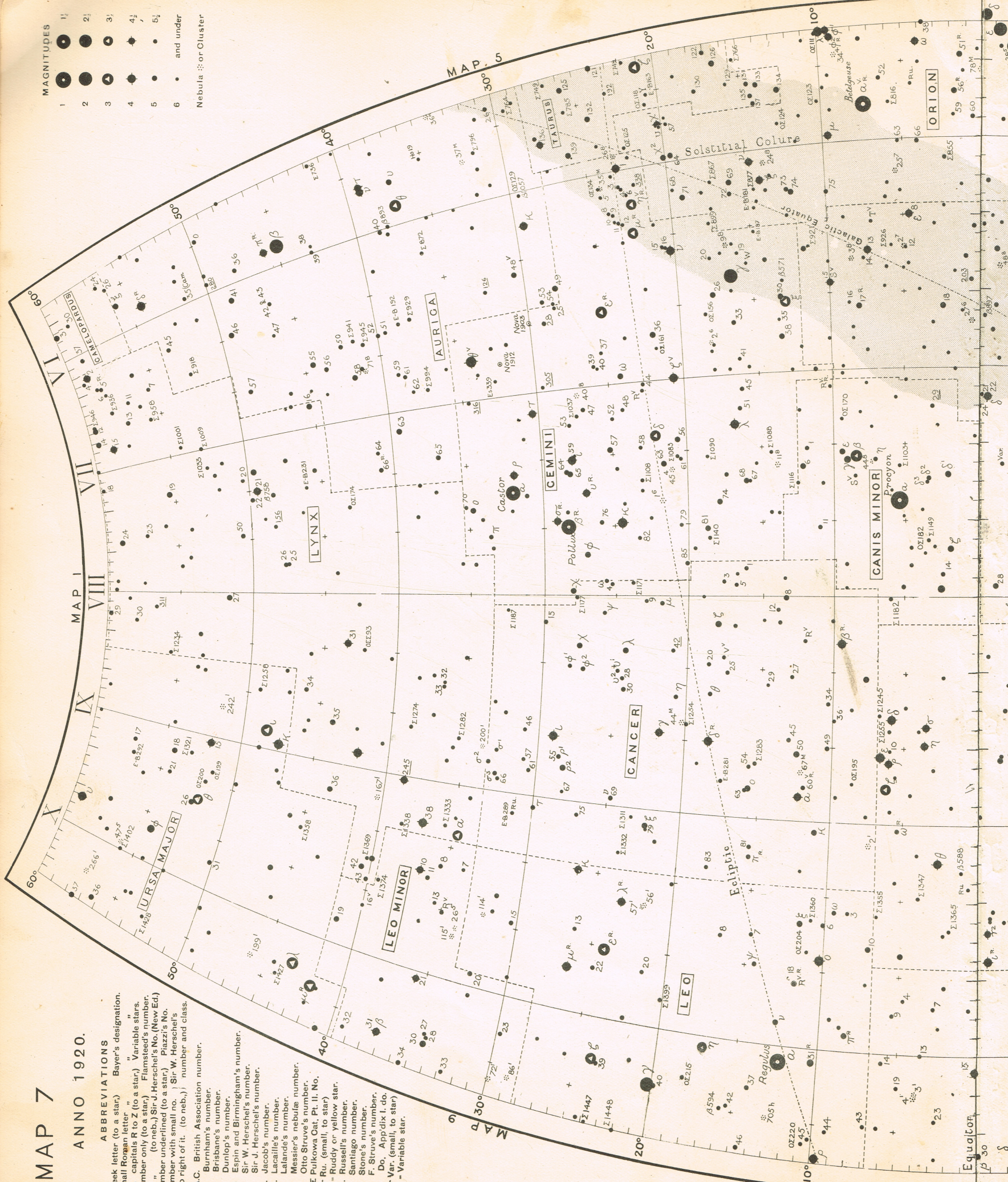
MAPS 7 AND 8
(VI hrs. to X hrs.)

MAP 7

ANNO 1920.

ABBREVIATIONS

Greek letter (to a star) Bayer's designation.
 Small Roman letter " capitals R to Z (to a star) " Variable stars.
 Number only (to a star) Flamsteed's number.
 (to neb.) Sir J. Herschel's No. (New Ed.)
 Number underlined (to a star) Piazzi's No.
 Number with small no. (to neb.) Sir W. Herschel's
 to right of it. (to neb.) number and class.
 B.A.C. British Association number.
 Br. Burnham's number.
 Br. Brisbane's number.
 Dunlop's number.
 E.B. Espin and Birmingham's number.
 h Sir W. Herschel's number.
 h Sir J. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 L.I. Lalande's number.
 M. Messier's number.
 O.S. Otto Struve's number.
 O.S.S. Pulkowa Obs. Pt. II, No.
 R or Ru. (small, to star)
 - Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 S. F. Struve's number.
 Z. Do. Appendix I. do.
 V or Var. (small, to star)
 - Variable star.



MAGNITUDES
 1 ●
 2 ●
 3 ●
 4 ●
 5 ●
 6 ● and under
 Nebula ☁ or Cluster



TELESCOPIC OBJECTS—MAPS 9 & 10.

DOUBLE STARS.

- α (12) CANUM VENATICORUM (*Cor Caroli*). 12h. 52m. N. 38° 45'. A double star. Magnitudes 3 and 6. Distance 20".
- 12 COMÆ BERENICES. 12h. 18m. N. 26° 15'. A $4\frac{1}{2}$ mag. star attended by one of $8\frac{1}{2}$ mag. at a distance of 66".
- δ CORVI. 12h. 26m. S. 16° 5'. A double star. The principal star is of the 3rd mag. and yellow. Magnitude of companion, $8\frac{1}{2}$. Distance 24".
- Σ 1669 CORVI. 12h. 37m. S. 12° 35'. A pair of equal $6\frac{1}{2}$ mag. stars. Distance 5.4".
- α LEONIS (*Regulus*). 10h. 4m. N. 12° 20'. Has a companion of the $8\frac{1}{2}$ mag., distant 177". The comes is also a double, but very difficult.
- γ LEONIS. 10h. 15m. N. 20° 15'. A beautiful object. It consists of a 2.6 mag. star with a 3.8 mag. companion 3.6" distant (1907). 3".9 (1925). Period 407 years.
- ι LEONIS. 11h. 20m. N. 11° 0'. A binary star. Magnitudes 4 and 7. Distance 2.4" (1906). 2" (1914).
- ξ URSÆ MAJORIS. 11h. 14m. N. 32° 0'. A fine binary star, with a period of about 61 years. The magnitudes of its components are $4\frac{1}{2}$ and 5, their distance 2.5" (1907). 3" (1913). Now closing (1921): closest, 0.9" (1933).
- γ VIRGINIS. 12h. 37m. S. 1° 0'. A very fine binary star, with a period of about 180 years.* In 1780 the distance of the components was 6". In 1836 they could only be seen as an elongated star. Since then they have gradually widened to 5.6" (1891): 6" (1914). The stars are both of the $3\frac{1}{2}$ magnitude.
- θ VIRGINIS. 13h. 6m. S. 5° 5'. A 4th mag. star with a 9th mag. comes, 7" distant. A severe test for a 3 in. telescope, though Ward glimpsed it with $2\frac{1}{4}$ in. in 1875.

VARIABLE STARS.

- η ARGÛS. 10h. 42m. S. 59° 15'. A most remarkable variable star, in a wonderful nebula. In 1677 it was 4th mag., rose to 2nd mag. in 1751, then sank to 4th mag. In 1827 it rose to 1st mag. and for about five years was 2nd mag. In 1837 it returned to 1st mag., faded slightly, and then in 1843 became almost as bright as Sirius. In 1862 it became invisible to the naked eye. It was 7th mag. in 1892 and $7\frac{1}{2}$ mag. in 1902. 7.8 mag. (1914).

NEBULÆ & STAR CLUSTERS. (N.G.C. Nos.:—M. 51=5194; M. 3=5272; ω Centauri=5139).

- M. 51 CANUM VENATICORUM. 13h. 26m. N. 47° 35'. A spiral nebula; but small telescopes will not show its formation.
- M. 3 CANUM VENATICORUM. 13h. 38m. N. 28° 45'. A beautiful globular cluster, but hardly resolvable into stars with a small telescope.
- 5139, ω CENTAURI. 13h. 22m., S. 46° 55'. A great and glorious globular cluster containing thousands of stars of 12th to 15th magnitude.

ADDENDA:

Distance of Double Stars. ι Leonis, 1".7 (1925); ξ Ursæ Maj., 2".5 (1926);
 γ Virginis, 5".8 (1922), closing, 5".7 (1925).

* 193.7 years, Burnham; 182 years, Lewis. Distance varies from 6".3 to 0".5

MAPS 9 AND 10
(X hrs. to XIV hrs.)

MAP 9

ANNO 1920.

ABBREVIATIONS

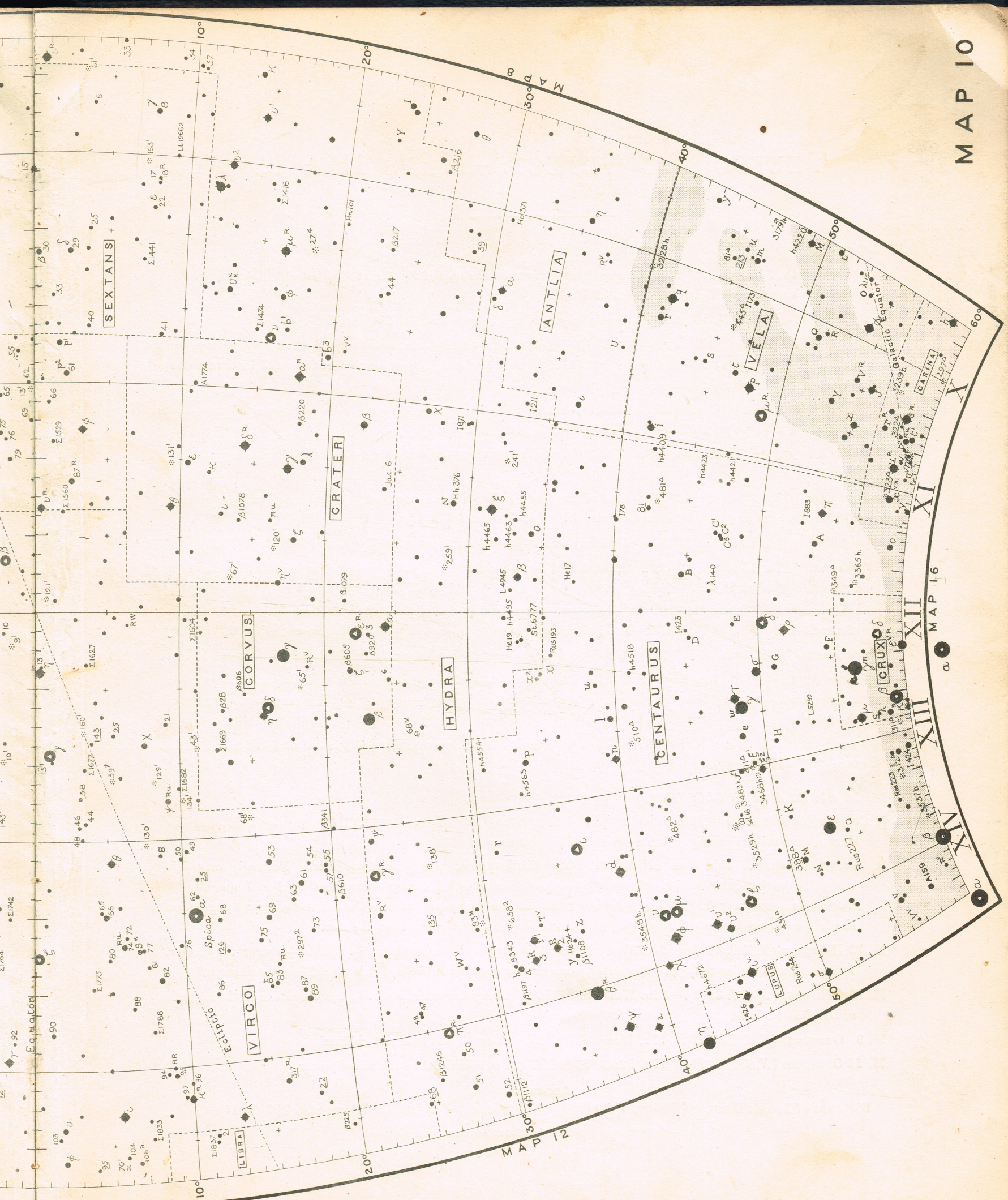
Greek letter (to a star) Bayer's designation.
 Small Roman letter " capitals R to Z (to a star) " Variable stars.
 " capitals R to Z (to a star) " Variable stars.
 Number only (to a star) Flamsteed's number.
 " (to neb.) Sir J. Herschel's No. (New Ed.)
 Number underlined (to a star) Piazzi's No.
 Number with small no. Sir W. Herschel's
 to right of it. (to neb.) number and class
 B.A.C. British Association number.
 β Burnham's number.
 Br. Brisbane's number.
 Δ Dunlop's number.
 E-B Espin and Birmingham's number.
 H Sir W. Herschel's number.
 h Sir J. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 L.L. Lalande's number.
 M Messier's nebula number.
 OZ Otto Struve's number.
 OZ Pulkova Cat. Pt. II. No.
 R or Ru. (small, to star)
 - Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 Σ F. Struve's number.
 Σ Do. Appendix I do.
 V or Var. (small, to star)
 - Variable star.

MAGNITUDES

1	2	3	4	5	6
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•

Nebula • or Cluster





TELESCOPIC OBJECTS—MAPS 11 & 12.

DOUBLE STARS.

- κ Boötis. 14h. 11m. N. 52° 10'. One of three stars near the end of the Great Bear's tail. A 5th mag. star with a 7th mag. attendant. Distance 12·6".
- π Boötis. 14h. 37m. N. 16° 45'. A double star. Magnitudes 5 and 6. Distance 5·8".
- ε Boötis (*Pulcherrima*). 14h. 42m. N. 27° 15'. A beautiful double star, consisting of a 3rd mag. yellow, and a 6½ mag. blue star, at 2·6" distance: 2·9" (1915). A most lovely object and a test for small instruments: well seen in 2½-inch achromatic.
- ξ Boötis. 14h. 48m. N. 19° 25'. A binary star. The magnitudes of its components are 4·7 and 6·6. Distance 3·2" (1891). 2·2" (1914). The period is 160 years.
- ζ Coronæ Borealis. 15h. 36m. N. 36° 55'. A white 4th mag. star with a greenish 6th mag. companion 6" distant.
- α Herculis. 17h. 11m. N. 14° 30'. One of the first doubles in the heavens. A 3rd mag. variable orange star with a blue or green attendant of the 6th mag., distant 4·6".
- 36 Ophiuchi. 17h. 10m. S. 26° 30'. A binary star. Two 6th mag. stars, 4·3" apart (1888), 4·2" (1905).
- 39 Ophiuchi. 17h. 13m. S. 24° 10'. A beautiful double star. A 5½ mag. orange star with a 6 mag. blue companion distant 10·6".
- ξ Scorpionis.* 16h. 0m. S. 11° 10'. A triple star. The magnitudes of the components are 5, 5, and 7. Their distances in 1888 were 1" and 7". In 1907 the nearer pair had closed up to 0·2". Now opening; 0·7" (1912).
- β Scorpionis. 16h. 1m. S. 19° 35'. A double star. The magnitudes are 2 and 4, and their distance 13".
- α Scorpionis (*Antares*). 16h. 24m. S. 26° 15'. A fiery red star of the first magnitude. It has a 7th mag. green companion 3" distant; but this can rarely be seen in small telescopes, owing to the overpowering glare of the large star.
- δ Serpentis. 15h. 31m. N. 10° 50'. A binary system. The components are of the 3rd and 4th mags. Distance 3·9" (1913).

VARIABLE STARS & STAR CLUSTERS.

- T Coronæ Borealis. 15h. 56m. N. 26° 10'. The "Blaze Star" flamed up to 2nd mag. in 1866, and has since decreased irregularly. 9th mag. in 1892. 9·4 mag. (1907).
- R Coronæ Borealis. 15h. 45m. N. 28° 24'. The third type of 'long-period variable.' Normally mag. 5·5, but after an irregular period of many months—sometimes of a year—decreases by 1 to 7 magnitudes (minimum about mag. 12½). The period of variation is of the same order as that of the constant phase, and the fall, contrary to that of other long-period variables, is more rapid than the rise.
- M. 13 Herculis (*N.G.C.* 6205). 16h. 39m. N. 36° 35'. A grand cluster between η and ζ—nearer the former. It is visible to the naked eye. The outer parts can be resolved into stars in a good 2½-inch telescope.
- M. 19 Ophiuchi (*N.G.C.* 6273). 16h. 57m. S. 26° 10'. A bright cluster, but low for observation in the latitude of the British Isles.
- M. 9 Ophiuchi (*N.G.C.* 6333). 17h. 14m. S. 18° 25'. A small but brilliant cluster.
- M. 23 Ophiuchi (*N.G.C.* 6494). 17h. 52m. S. 19° 0'. A splendid field with a low power.

ADDENDA:

Distance of Double Stars. ξ Boötis, 3"·0 (1925); 36 Ophiuchi., 4"·2 (1924); δ Serpentis, 3"·7 (1924).

* Note.—SCORPII, the genitive of SCORPIUS, is now generally used.

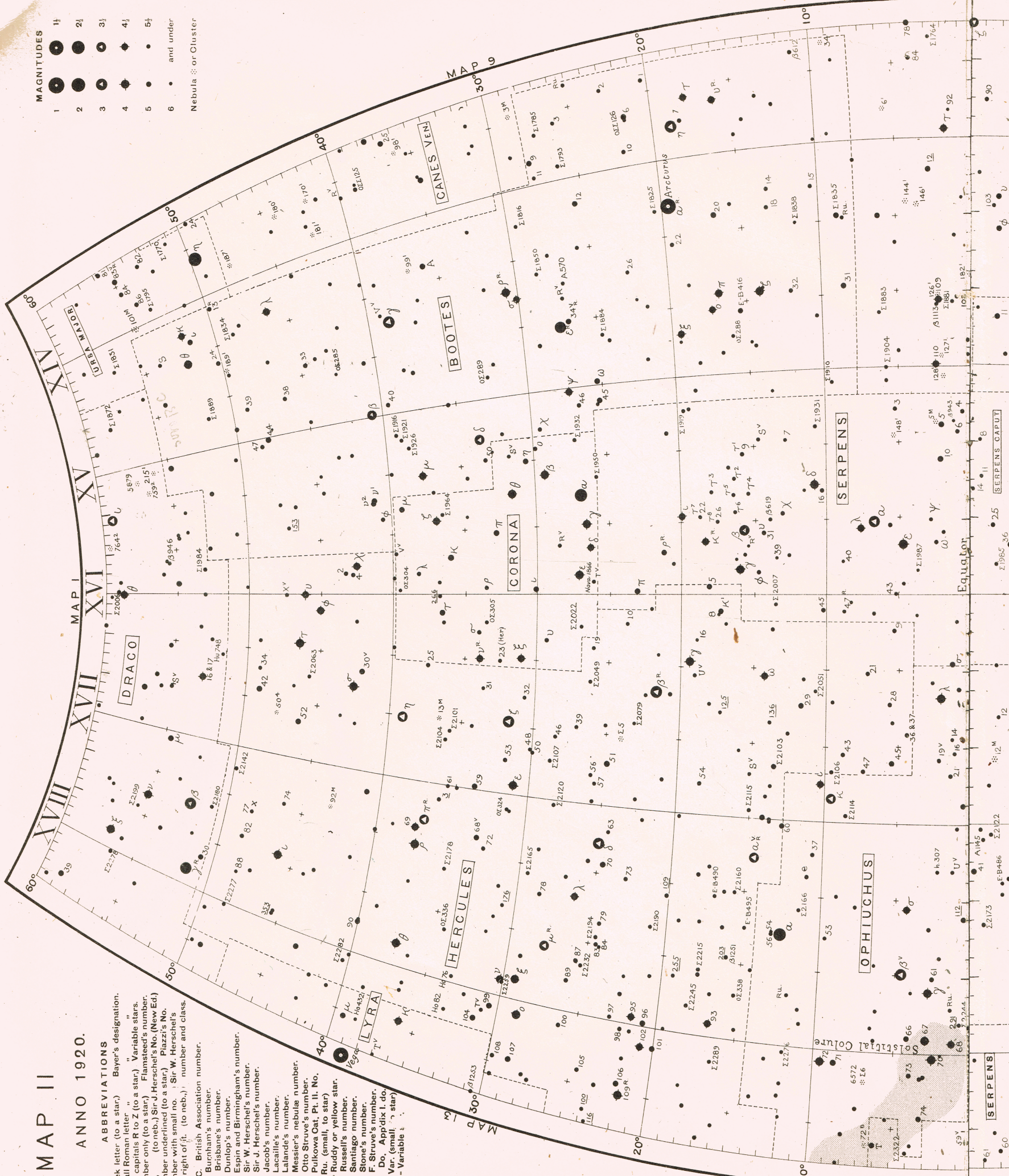
MAPS 11 AND 12
(XIV hrs. to XVIII hrs.)

MAP II

ANNO 1920.

ABBREVIATIONS

Greek letter (to a star) Bayer's designation.
 Small Roman letter " " Variable stars.
 Number only (to a star) Flamsteed's number.
 " (to neb.) Sir J. Herschel's No. (New Ed.)
 Number underlined (to a star) Plazzi's No.
 Number with small no. Sir W. Herschel's
 to right of it. (to neb.) number and class.
 B.A.C. British Association number.
 β Burnham's number.
 Br. Brisbane's number.
 Δ Dunlop's number.
 E-B Espin and Birmingham's number.
 h Sir W. Herschel's number.
 h Sir J. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 L.I. Lalande's number.
 M. Messier's number.
 O.S. Otto Struve's number.
 O.S.I. Pulikova-Ost. Pt. II. No.
 R or Ru. (small, to star)
 - Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Stone's number.
 St. F. Struve's number.
 Z. Do. Appendix I. do.
 V or Var. (small, to star)
 - Variable



MAGNITUDES
 1 ●
 2 ●
 3 ●
 4 ●
 5 ●
 6 ● and under
 Nebula ☉ or Cluster



TELESCOPIC OBJECTS—MAPS 13 & 14.

DOUBLE STARS.

- ζ AQUARI. 22h. 25m. S. 0° 25'. A beautiful object. Two 4th mag. stars at a distance of 3" (1892).
- 15 AQUILÆ. 19h. 1m. S. 4° 10'. A double star. The components are of 6 and 7½ mags., and their colours yellow and ruddy. Distance 34". About 1° N. of λ and slightly preceding it.
- π AQUILÆ. 19h. 45m. N. 11° 35'. A double star with components of the 6th and 7th mags. Distance 1·4". A test object for a 3 in. telescope.
- α CAPRICORNI. 20h. 13m. S. 12° 45'. A grand naked-eye pair. The stars are of the 3rd and 4th magnitudes and 6' 16" apart.
- β CYGNI. 19h. 27m. N. 27° 45'. A magnificent double star. A 3rd mag. golden-yellow star with a blue attendant of 5½ mag. Distance 34".
- 61 CYGNI. 21h. 3m. N. 38° 20'. The first star to have its distance measured, by Bessel. A double star. Magnitudes 5½ and 6, nearly equal. Distance 21". 23·5" (1913).
- μ CYGNI. 21h. 40m. N. 28° 25'. A double star. Magnitudes 4½ and 6. Distance 5·6". 1·7" (1914).
- γ DELPHINI. 20h. 43m. N. 15° 50'. A beautiful and easy double star. The magnitudes are 4 and 5, and their distance 11".
- α LYRÆ (*Vega*). 18h. 34m. N. 38° 40'. Is considered by some to be the second brightest fixed star. It has a 10th mag. attendant 52" off, which has been seen on rare occasions with smaller apertures, but is a hard test for a 3 in. telescope. There are several distant small stars in the field.
- ε¹ and ε² LYRÆ. 18h. 42m. N. 39° 30'. The "Double-double." The two stars have been seen by the naked eye by several observers: to most they appear elongated. ε¹ has components of mags. 4½ and 6½ at 3" distance; ε² of 5 and 5·2 mag. at 2·3" distance. Between the pairs are 3 other stars, two of them very faint.

NEBULÆ & STAR CLUSTERS. (*N.G.C. Nos.*—*M.2*=7089; *M.11*=6705; *M.57*=6720; *M.20*=6514; *M.8*=6523; *M.27*=6853).

- M.2* AQUARI. 21h. 29m. S. 1° 10'. A magnificent globular cluster of 5' or 6' diameter.
- M.11* AQUILÆ. 18h. 46m. S. 6° 20'. A grand cluster, just visible to the naked eye.
- M.57* LYRÆ. 18h. 51m. N. 32° 55'. The "Ring Nebula," between β and γ. Its form may be seen in a 2½ in. telescope. It bears magnifying well.
- M.20* SAGITTARI. 17h. 57m. S. 23° 0'. The "Trifid Nebula." In large telescopes, three dark rifts are seen to meet in the middle of the nebula.
- M.8* SAGITTARI. 17h. 59m. S. 24° 20'. A splendid cluster. Fine low-power field.
- M.27* VULPECULÆ. 19h. 56'. N. 22° 30'. The "Dumb-bell Nebula," so called from its appearance in moderate-sized telescopes.

VARIABLE STARS.

- Nova AQUILÆ 3 (1918). R.A. 18h. 45m., Dec. 0° 29'N. At its brightest it was about mag. 0·1.
- β LYRÆ. 18h. 47m. N. 33° 16'. The typical 'Lyrid' ('short-period') variable. It has two equal maxima with a slight intervening minimum, then a sharp drop to a great minimum, and corresponding sharp rise to maximum. Period, 12d. 22h.; maximum mag. 3·4; minimum, 3·8 to 4·1. The variations are due to the mutual eclipse of two unequally bright stars.
- χ CYGNI. 19h. 48m. N. 32° 43'. A long-period variable of the *Mira* type. Maximum mag. 4·2; min., 13·7. Period 406 days. The total radiation of this star varies 1·7 times; the light, 1320-fold.

ADDENDA:

Distance of Double Stars. ζ Aquarii, 2"·8 (1921); 61 Cygni, 24" (1925); μ Cygni 1"·4 (1924).

MAPS 13 AND 14
(XVIII hrs. to XXII hrs.)

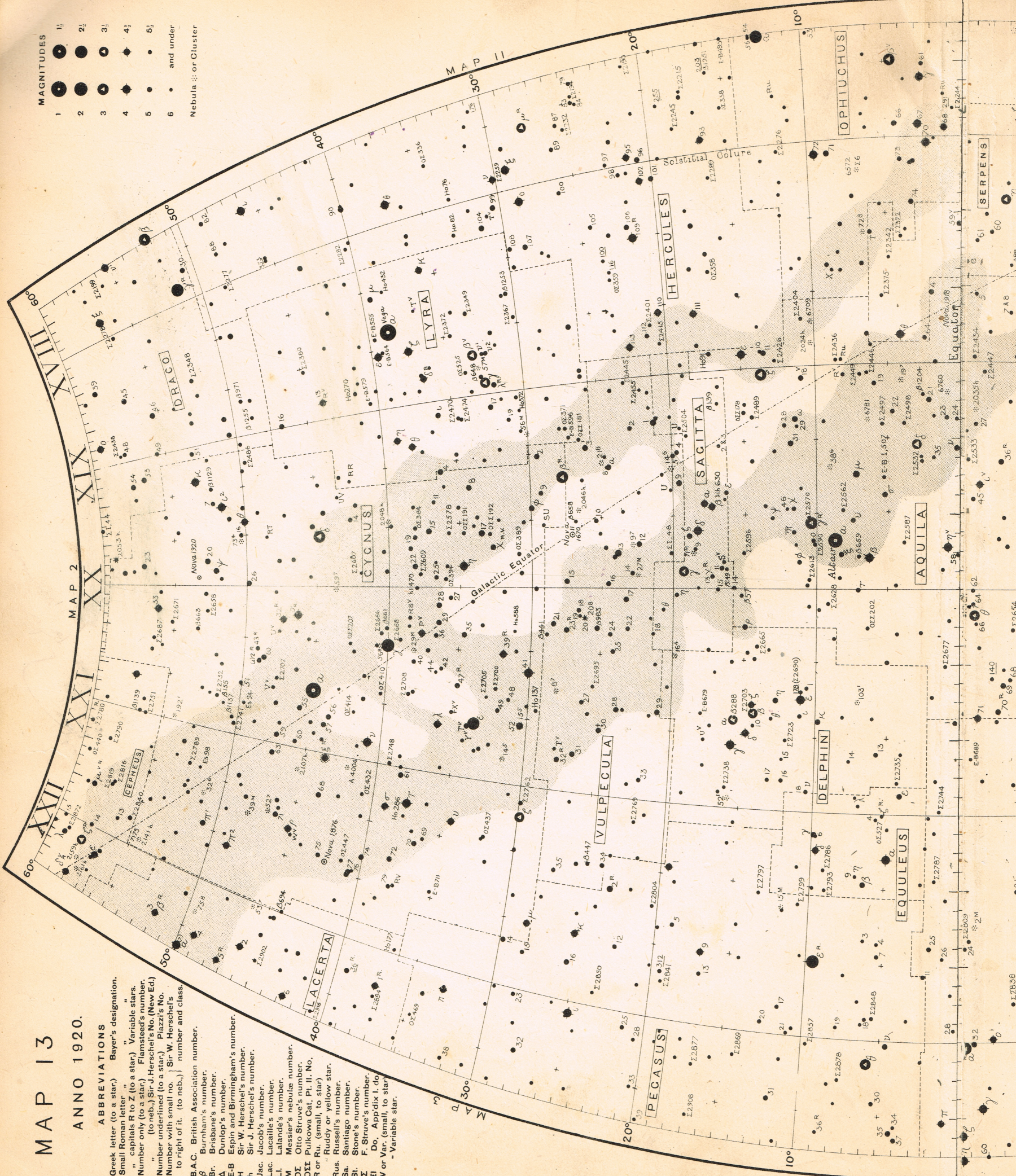
MAP 13

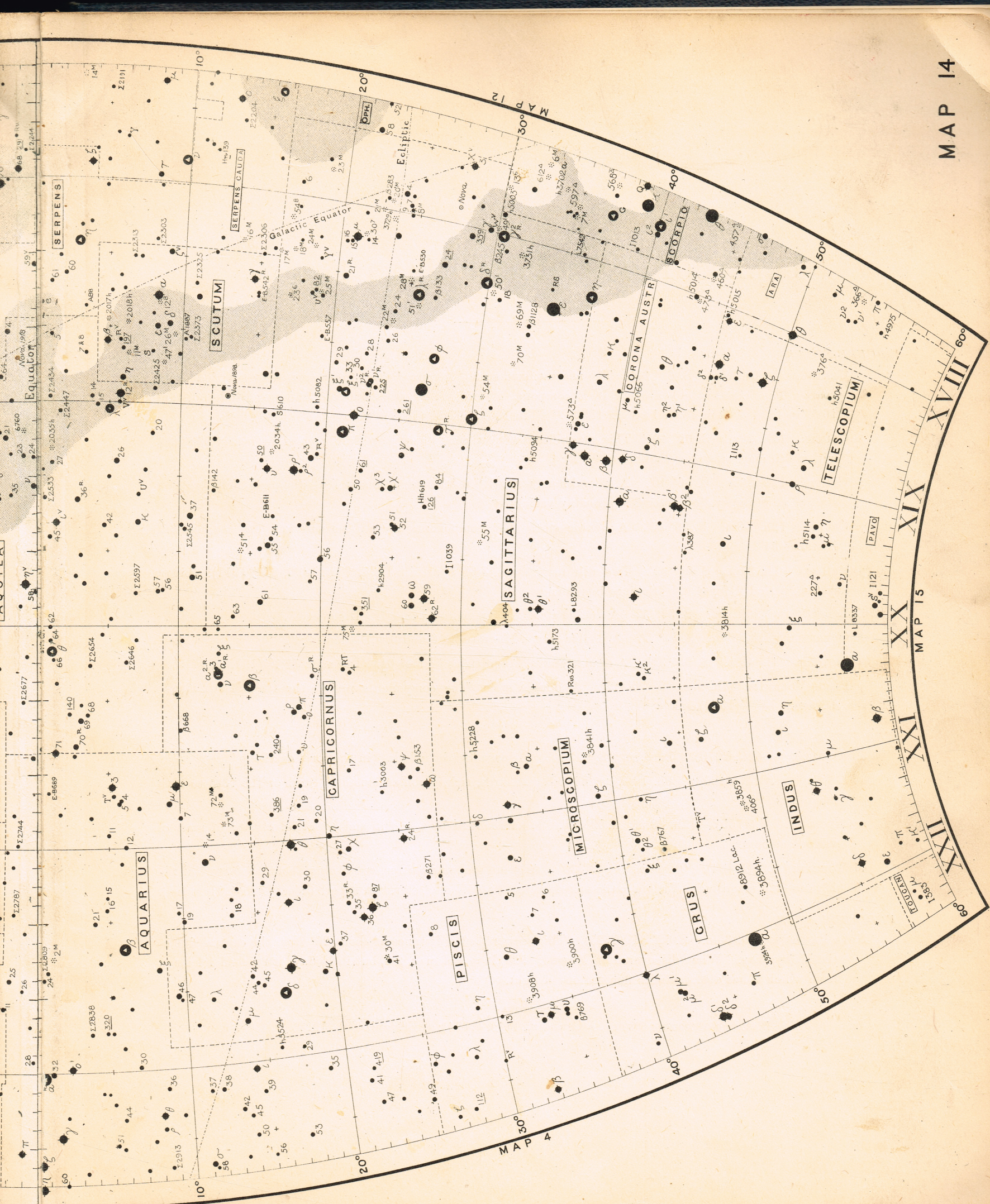
ANNO 1920.

ABBREVIATIONS

Greek letter (to a star) Bayer's designation.
 Small Roman letter " capitals R to Z (to a star) Variable stars.
 " " (to a star) Flamsteed's number.
 " " (to a star) Sir J. Herschel's No. (New Ed.)
 Number underlined (to a star) Piazzi's No.
 Number with small no. (to a star) Sir W. Herschel's
 to right of it. (to neb.) number and class.
 B.A.C. British Association number.
 Br. Burnham's number.
 B. Brisbane's number.
 D. Dunlop's number.
 E-B Espin and Birmingham's number.
 h Sir W. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 L. Lalande's number.
 M. Messier's number.
 O.E. Otto Struve's number.
 O.E. Pulkova Cat. Pt. II, No.
 R or Ru. (small, to star) Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 S. Struve's number.
 Do. Appendix I, do.
 V or Var. (small, to star) Variable star.

MAGNITUDES
 1 2 3 4 5 6
 and under
 Nebula :: or Cluster





TELESCOPIC OBJECTS—MAPS 15 & 16.

DOUBLE STARS.

- α CENTAURI. 14h. 34m. S. $60^{\circ} 30'$. The nearest fixed star. A remarkable binary star, with a period of 81 years. The finest in the heavens. It is composed of two yellow stars, 1st and 2nd magnitudes, distant $16\cdot5''$ in 1836, $7\cdot6''$ in 1851, $18\cdot6''$ in 1890, $21\cdot6''$ in 1902. $15\cdot5''$ (1917). Closest, $4''$ (1939).
- α CRUCIS. 12h. 22m. S. $62^{\circ} 40'$. This magnificent object consists of two 2nd mag. stars, nearly $5''$ apart, with a 6th mag. star at a distance of $90''$.
- γ CRUCIS. 12h. 26m. S. $56^{\circ} 40'$. A second mag. star with a 5th mag. *comes* at $101''$ distance. The brighter star, of an orange-yellow colour, is probably variable.
- μ CRUCIS. 12h. 50m. S. $56^{\circ} 45'$. A double star. The components are of the 5th and 6th magnitudes. Distance $34''$.
- 6 (p) ERIDANI. 1h. 37m. S. $56^{\circ} 35'$. Two 6th mag. stars $3\cdot6''$ apart in 1835, $7''$ in 1890, $8\cdot3''$ (1911): a binary system, period 219 years. Distance increasing
- 9367 Lac. GRUIS. 23h. 3m. S. $51^{\circ} 5'$. A double star. Magnitudes $6\frac{1}{2}$ and 7. Distance $8''$.
- λ OCTANTIS. 21h. 39m. S. $83^{\circ} 5'$. A double star. Magnitudes 6 and 9. Distance $3\cdot4''$.
- ι PICTORIS. 4h. 49m. S. $53^{\circ} 35'$. A double star. Magnitudes $5\frac{1}{2}$ and $6\frac{1}{2}$. Distance $11\cdot1''$ (1902).
- γ PISCIS VOLANTIS. 7h. 9m. S. $70^{\circ} 25'$. A double star. The components are of the 4th and 6th mags. Distance $13''\cdot7$ (1922).

NEBULÆ & STAR CLUSTERS.

- 30 DORADUS (*N.G.C.* 2070). 5h. 39m. S. $69^{\circ} 10'$. A large, bright nebula "in the form of a loop."
- 265 Δ CARINÆ (*N.G.C.* 2808). 9h. 10m. S. $64^{\circ} 30'$. A large, rich, globular cluster. Stars of the 13th to 15th magnitude.
- κ CRUCIS (*N.G.C.* 4755). 12h. 49m. S. $59^{\circ} 55'$. Is surrounded by a bright and beautiful cluster of stars of various colours.
- 47 TOUCANI (*N.G.C.* 104). 0h. 20m. S. $72^{\circ} 30'$. A grand globular cluster, containing about 1500 stars of the 12th to 14th magnitude. Visible to the naked eye as a hazy $4\frac{1}{2}$ mag. star. "A superb object" (Sir J. Herschel).

VARIABLE STAR.

- NOVA PICTORIS. 6h. 35m. S. $62^{\circ} 34'$ (1925). This appeared at a distance of about 26° from the central line of the Milky Way. When discovered on May 25, 1925, it was of mag. $2\cdot4$, but in 15 days it reached $1\cdot1$ mag., from which it has declined with fluctuations of light.

ADDENDA:

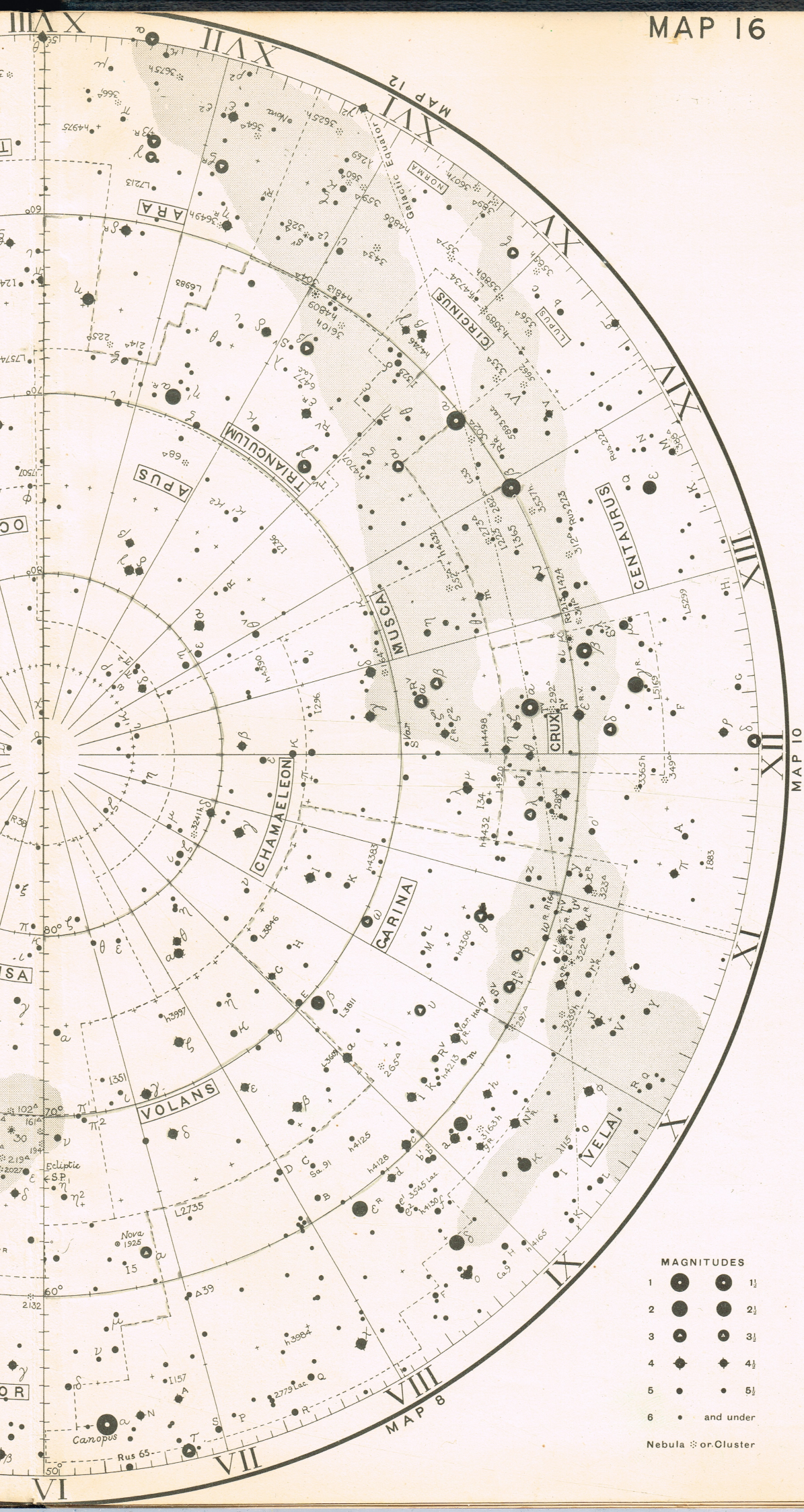
Distance of Double Stars. α Centauri, $11''\cdot2$ (1924); 6 Eridani, $9''\cdot1$ (1922).

MAPS 15 AND 16
(Circumpolar, South)

ABBREVIATIONS

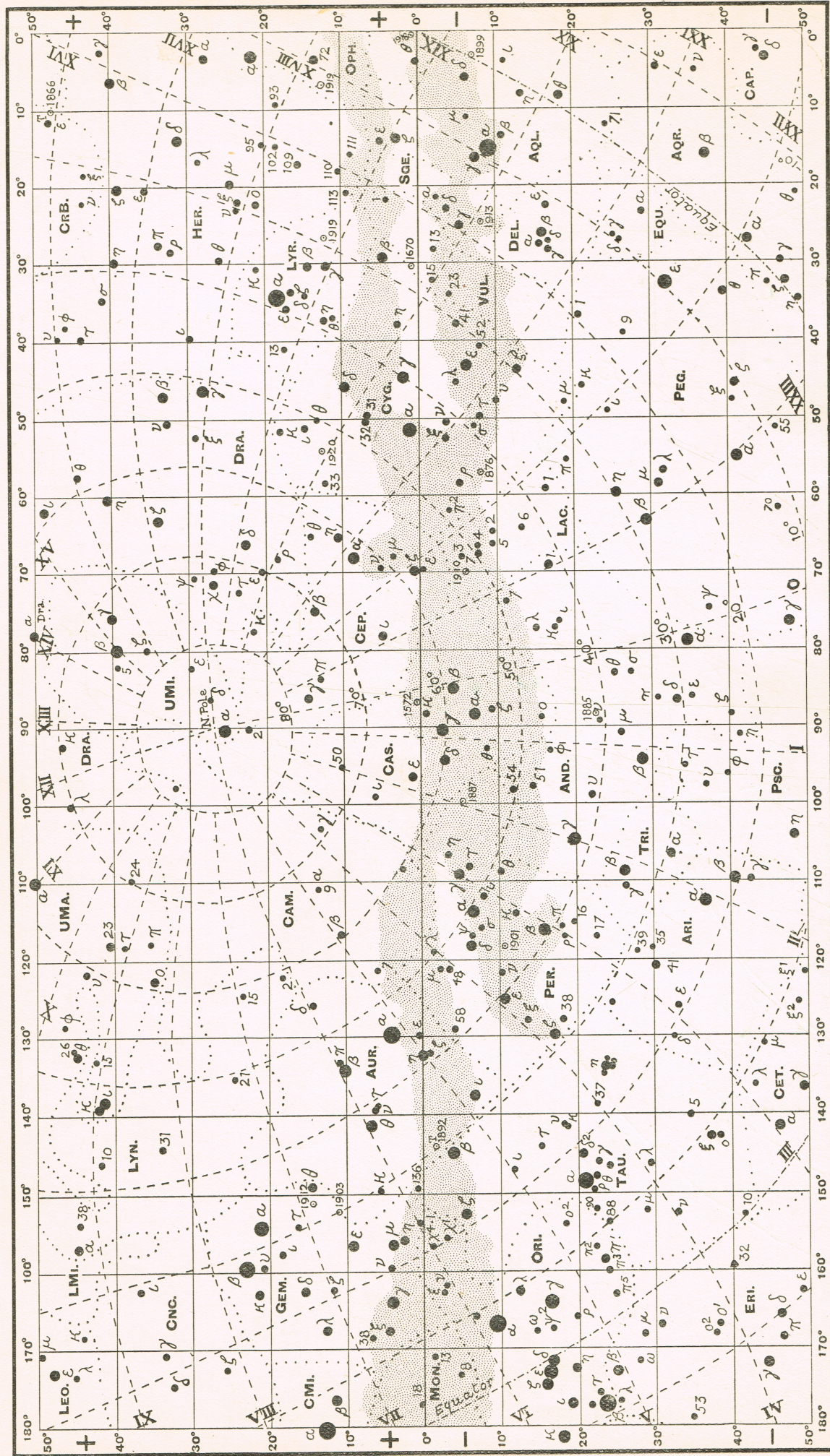
Greek letter (to a star), Bayer's designation.
Small Roman letter " Variable stars.
" capitals R to Z (to a star), " Number only (to a star), Flamsteed's number.
" (to neb.), Sir J. Herschel's No. (New Ed.)
Number underlined (to a star), Piazzzi's No.
Number with small no., Sir W. Herschel's
to right of it. (to neb.), number and class.

B.A.C. British Association number.
 β Burnham's number.
 Br. Brisbane's number.
 Δ Dunlop's number.
 E-Espin and Birmingham's number.
 H Sir W. Herschel's number.
 h Sir J. Herschel's number.
 Jac. Jacob's number.
 Lac. Lacaille's number.
 L. Lalande's number.
 M. Messier's nebula number.
 OS Otto Struve's number.
 OS Σ Pulkowa Cat. Pt. II. No.
 R or Ru. (small, to star)
 - Ruddy or yellow star.
 Rus. Russell's number.
 Sa. Santiago number.
 St. Stone's number.
 Z F. Struve's number.
 Σ Do, App'dix I. do.
 V or Var. (small, to star)
 - Variable star.



MAP 17.

GALACTIC CHART (Galactic Longitude 0° to 180°; Galactic Latitude 50° N. to 50° S.)



Novae ○

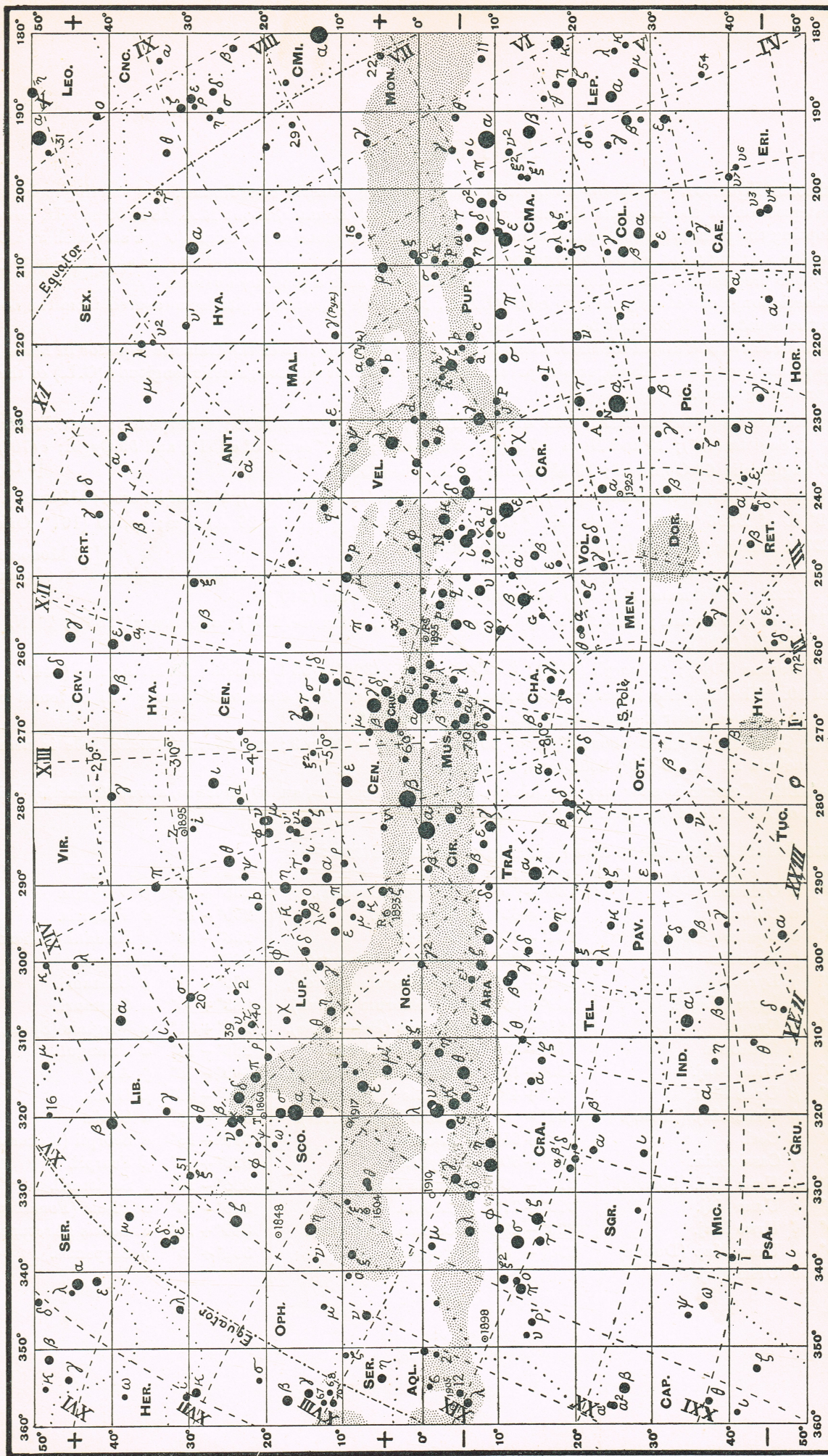
0 1 15 2 25 3 35 4 45

The stippled area represents the general position of the Milky Way

MAP 18.

(Galactic Longitude 180° to 360°; Galactic Latitude 50° N. to 50° S.)

GALACTIC CHART



Novae ○



The stippled area represents the general position of the Milky Way

APPENDIX

The Galactic Equator.—Different authorities adopt varying galactic co-ordinates, the starting point being usually the intersection of the Galactic Equator with the Celestial Equator, about R.A. 18 h. 50 m. If, however, instead of adopting the point where the equator intersects the galactic plane as the origin (0°), a star such as α Cygni were taken as the starting point, as has been proposed, the galactic co-ordinates would not be affected—as they are at present—by the precession of the equinoxes. The advantages of such a plan are obvious.

If the galactic longitude of α Cygni is to be 0° (I.A.U. 1925) the galactic longitudes measured from the node of the galaxy in the equator of 1900 must be diminished by about 51° .

It will be instructive and useful for the student to insert in pencil the line of the Galactic Equator in Maps 1-16, by joining the points here given. The figures in parentheses give the approximate galactic longitude (G.L.) of the star immediately preceding them.

MAP 13. Intersects equator at R.A., 18h. 42m. (G.L. 0°); Nova Aquilæ, 1918; θ Serpentis; near R Aquilæ; 2 Sagittæ (19°); 10 and Nova 1670, (30°) Vulpeculæ; 29, 1° south of α (51°), and 59 Cygni; ϵ (70°) and

MAP 14. 3 Sagittarii; 63 Ophiuchi; 16 M Aquilæ; 5 Aquilæ (359°). [δ Cephei.

MAP 2. ϵ and δ Cephei; 4 (80°) 6 and κ (87°) Cassiopeia; 1° S. of ϵ Cassiopeia (87°); 2° N. of λ Persei; b^1 Persei (120°).

MAP 5. 2° S. of $\Sigma 396$ (110°); b^1 Persei; ζ (132°), μ , ϕ (140°), χ (143°), 26 Aurigæ; χ^4 , 69 (161°) Orionis;

MAP 7. $\Sigma 764$ Aurigæ; χ^4 , 69 Orionis; 13 Monocerotis (171°). [13 Monocerotis.

MAP 8. Crosses equator at R.A. 6h. 42m. (180°); 50 M. Monocerotis (189°); R Canis Majoris; 1° S. of q Puppis (222°); g Velorum, 1° S. of c Velorum (235°), K Velorum (240°).

MAP 16. 1° S. of ϕ Velorum; s (252°), t^2 , η Carinae (254°); θ , α Crucis (267°); α Centauri (283°); 1° N. of β Circini (288°).

MAP 12. γ^2 Normæ (301°); ζ^2 Scorpii (310°); 3 (X) Sagittarii (328°); 63 Ophiuchi; 16 M. Aquilæ (344°).

MAPS 3 and 10. The Galactic Equator cuts across near a corner. The stars on its course will be found in the lists above under the heading of Maps 2, 13, 8 and 16.

The North Galactic Pole is about 1° S. of 30 Comæ Ber. in Map 9; the South Galactic Pole is near the nebula H. VI. 20 (20°) Sculptoris, in Map 4.

The Galactic Centre is near the junction of Sagittarius, Scorpius, and Ophiuchus, about (Galactic) latitude 0° , longit. 327° , or R.A. 17h. 40m., Dec. 30° S.

Approximate Galactic Longitude and Latitude of certain Stars:—

Long.	Lat.	Star	Long.	Lat.	Star	Long.	Lat.	Star
$3^\circ + 22^\circ$		α Ophiuchi.	$130^\circ + 5^\circ$		α Aurigæ (Capella).	$238^\circ + 61^\circ$		β Virginis.
$10^\circ + 54^\circ$		α Coronæ.	$130^\circ + 63^\circ$		ψ Ursæ Maj.	$250^\circ - 12^\circ$		α Volantis.
$15^\circ - 9^\circ$		α Aquilæ (Altair).	$134^\circ + 10^\circ$		β Aurigæ.	$258^\circ - 58^\circ$		α Eridani (Achernar).
$20^\circ + 40^\circ$		ζ Herculis.	$148^\circ - 20^\circ$		α Tauri (Aldebaran).	$267^\circ + 0^\circ$		α Crucis.
$30^\circ + 12^\circ$		γ Lyræ.	$154^\circ + 22^\circ$		α Geminorum (Castor).	$279^\circ + 1^\circ$		β Centauri.
$35^\circ + 19^\circ$		α Lyræ (Vega).	$159^\circ + 23^\circ$		β Geminorum (Pollux).	$283^\circ + 0^\circ$		α Centauri.
$45^\circ + 1^\circ$		γ Cygni.	$167^\circ - 9^\circ$		α Orionis (Betelgeuse).	$283^\circ + 51^\circ$		α Virginis (Spica).
$60^\circ + 40^\circ$		η Draconis.	$176^\circ - 25^\circ$		β Orionis (Rigel).	$288^\circ - 15^\circ$		α Trianguli.
$67^\circ + 65^\circ$		η Ursæ Maj.	$180^\circ + 13^\circ$		α Canis Min. (Procyon).	$300^\circ - 8^\circ$		ζ Aræ.
$80^\circ + 40^\circ$		β Ursæ Min.	$192^\circ + 49^\circ$		α Leonis (Regulus).	$314^\circ - 58^\circ$		β Gruis.
$80^\circ + 61^\circ$		ζ Ursæ Maj. (Mizar).	$194^\circ - 8^\circ$		α Canis Maj. (Sirius).	$317^\circ - 52^\circ$		α Gruis.
$80^\circ - 80^\circ$		β Ceti.	$200^\circ + 65^\circ$		θ Leonis.	$319^\circ + 16^\circ$		α Scorpii (Antares).
$90^\circ - 2^\circ$		γ Cassiopeia.	$209^\circ + 30^\circ$		α Hydræ.	$320^\circ + 24^\circ$		β Scorpii.
$90^\circ + 26^\circ$		α Ursæ Min. (Polaris)	$210^\circ - 6^\circ$		η Canis Maj.	$326^\circ - 10^\circ$		ϵ Sagittarii.
$90^\circ + 61^\circ$		ϵ Ursæ Maj.	$215^\circ + 71^\circ$		β Leonis.	$345^\circ - 65^\circ$		α Piscis (Fomalhaut).
$100^\circ + 59^\circ$		δ Ursæ Maj.	$229^\circ - 25^\circ$		α Carinae (Canopus).	$345^\circ + 70^\circ$		α Boötis (Arcturus).
$110^\circ + 50^\circ$		α Ursæ Maj. (Dubhe)	$230^\circ - 8^\circ$		γ Puppis.	$354^\circ + 5^\circ$		η Serpentis.
$120^\circ + 45^\circ$		v Ursæ Maj.						

LIST OF STAR NAMES.

Name.	=
<i>Achernar</i> ...	α Eridani.
<i>Acrab, Akrab</i> ...	β Scorpionis.
<i>Adara</i> ...	ϵ Canis Majoris.
<i>Albireo</i> ...	β Cygni.
<i>Alchiba, Al-khiba</i> ...	α Corvi.
<i>Alcor</i> ...	80 Ursæ Majoris.
<i>Alcyone</i> (a Pleiad) ...	η Tauri.
<i>Aldebaran</i> ...	α Tauri.
<i>Alderamin</i> ...	α Cephei.
<i>Algeiba, Algieba</i> ...	γ Leonis.
<i>Algenib</i> ...	γ Pegasi.
<i>Algol</i> ...	β Persei.
<i>Algorab, Algorel, Algores</i> ...	δ Corvi.
<i>Alhena</i> ...	γ Geminorum.
<i>Alioth</i> ...	ϵ Ursæ Majoris.
<i>Alkaid</i> (Benetnasch) η Ursæ Majoris.	
<i>Alkalurops</i> ...	μ^1 Boötis.
<i>Alkes</i> ...	α Crateris.
<i>Almak, Almach</i> ...	γ Andromedæ.
<i>Alnilam</i> ...	ϵ Orionis.
<i>Alphard</i> (Cor Hydræ) α Hydræ.	
<i>Alphecca, Alphekka</i> α Coronæ Borealis.	
<i>Alpheratz, Alpherat</i> } α Andromedæ.	
(Sirrah)	
<i>Alphirk</i> ...	β Cephei.
<i>Alrai</i> (Errai) ...	γ Cephei.
<i>Alruccabah</i> (Polaris) α Ursæ Minoris.	
<i>Alshain, Alshairn</i> ...	β Aquilæ.
<i>Altair</i> ...	α Aquilæ.
<i>Alwaid</i> ...	β Draconis.
<i>Antares</i> (Cor Scorpionis) α Scorpionis.	
<i>Arcturus</i> ...	α Boötis.
<i>Arided</i> (Deneb Adige) ...	α Cygni.
<i>Arneb</i> ...	α Leporis.
<i>Asterope</i> (a Pleiad) ...	21 Tauri.
<i>Atlas</i> (a Pleiad) ...	27 Tauri.
<i>Azelfafage</i> ...	π^1 Cygni.
<i>Azimech</i> (Spica) ...	α Virginis.
<i>Baten Kaitos</i> ...	ζ Ceti.
<i>Bellatrix</i> ...	γ Orionis.
<i>Benetnasch</i> ...	η Ursæ Majoris.
<i>Betelgeux, Betelgeuze</i> ...	α Orionis.
<i>Canopus</i> ...	α Argûs.
<i>Capella</i> ...	α Aurigæ.
<i>Caph, Chap</i> ...	β Cassiopeiæ.
<i>Castor</i> ...	α Geminorum.
<i>Cor Caroli</i> ...	α Canum Venaticorum.
<i>Cor Hydræ</i> (Alphard) ...	α Hydræ.
<i>Cor Leonis</i> (Regulus) ...	α Leonis.

Name.	=
<i>Cor Scorpionis</i> (Antares) α Scorpionis.	
<i>Cor Serpentis</i> (Unukalhay) α Serpentis	
<i>Cursa, Kursa</i> ...	β Eridani.
<i>Deneb, Deneb Aleet,</i> } β Leonis.	
<i>Denebola</i> ... }	
<i>Deneb Algiedi</i> ...	δ Capricorni.
<i>Deneb, Deneb el Adige</i> } α Cygni.	
(Arided) ... }	
<i>Deneb Kaitos shemali</i> ...	ι Ceti.
<i>Diphda</i> (Deneb Kaitos jenubi) β Ceti.	
<i>Dubhe</i> ...	α Ursæ Majoris.
<i>Electra</i> (a Pleiad) ...	17 Tauri.
<i>Enif, Eniph</i> (Fom) ...	ϵ Pegasi.
<i>Errai</i> (Alrai) ...	γ Cephei.
<i>Etamin, Etanin</i> ...	γ Draconis.
<i>Fom</i> (Enif) ...	ϵ Pegasi.
<i>Fomalhaut</i> ...	α Piscis Australis.
<i>Gemma</i> ...	α Coronæ Borealis.
<i>Giedi</i> ...	α Capricorni.
<i>Gomeisa</i> ...	β Canis Minoris.
<i>Hamal</i> ...	α Arietis.
<i>Homam, Homan</i> ...	ζ Pegasi.
<i>Izar</i> (Mizar, Mirac) ...	ϵ Boötis.
<i>Kaitain</i> (Okda) ...	α Piscium.
<i>Kaus Australis</i> ...	ϵ Sagittarii.
<i>Keid</i> ...	40 Eridani.
<i>Kelb al Rai, Celb al Rai</i> β Ophiuchi.	
<i>Kocab, Kochab</i> ...	β Ursæ Minoris.
<i>Kornephoros</i> ...	β Herculis.
<i>Kursa, Cursa</i> ...	β Eridani.
<i>Maia</i> (a Pleiad) ...	20 Tauri.
<i>Markab</i> ...	α Pegasi.
<i>Marsik</i> ...	κ Herculis.
<i>Mebstuta</i> ...	ϵ Geminorum.
<i>Megrez</i> ...	δ Ursæ Majoris.
<i>Mekab, Menkab, Menkar</i> ...	α Ceti.
<i>Menkalinan</i> ...	β Aurigæ.
<i>Merak</i> ...	β Ursæ Majoris.
<i>Merope</i> (a Pleiad) ...	23 Tauri.
<i>Mesarthim, Mesartim</i> ...	γ Arietis.
<i>Mintaka</i> ...	δ Orionis.
<i>Mira</i> ...	$\circ$ Ceti.
<i>Mirac, Mirach</i> ...	β Andromedæ.
<i>Mirac, Mirach</i> (Izar) ...	ϵ Boötis.
<i>Mirfak, Mirphak</i> ...	α Persei.
<i>Mirzam</i> ...	β Canis Majoris.
<i>Mizar</i> ...	β Andromedæ.
<i>Mizar</i> ...	ϵ Boötis.
<i>Mizar</i> ...	ζ Ursæ Majoris.

Name.	=
<i>Muphrid</i> ...	η Bootis.
<i>Nath</i> ...	β Tauri.
<i>Nekkar</i> ...	β Boötis.
<i>Okda</i> (Kaitain) ...	α Piscium.
<i>Phakt, Phact</i> ...	α Columbæ.
<i>Phecda, Phekha</i> ...	γ Ursæ Majoris.
<i>Pleione</i> (a Pleiad) ...	28 Tauri.
<i>Polaris</i> ...	α Ursæ Minoris.
<i>Pollux</i> ...	β Geminorum.
<i>Prima Giedi</i> ...	α^1 Capricorni.
<i>Procyon</i> ...	α Canis Minoris.
<i>Pulcherrima</i> ...	ϵ Boötis.
<i>Ras Algethi, Rasalegti</i> α Herculis.	
<i>Ras Alhagua, Ras-al-hague</i> α Ophiuchi.	
<i>Rastaban, Rasaben</i> γ Draconis.	
<i>Regulus</i> (Cor Leonis) ...	α Leonis.
<i>Rigel</i> ...	β Orionis.
<i>Rotanev</i> ...	β Delphini.
<i>Sadachbia</i> ...	γ Aquarii.
<i>Sadalmelik, Sadalmulk</i> α Aquarii.	
<i>Sadalsud, Sadalsund</i> β Aquarii.	
<i>Secunda Giedi</i> ...	α^2 Capricorni.
<i>Sheat, Sheat</i> ...	β Pegasi.
<i>Schedir, Shedir, Schedar</i> α Cassiopeiæ.	
<i>Sheliak</i> ...	β Lyræ.
<i>Sheratan, Sharatain</i> β Arietis.	
<i>Sirius</i> ...	α Canis Majoris.
<i>Sirrah</i> (Alpheratz) α Andromedæ.	
<i>Skat, Sheat, Scheat</i> δ Aquarii.	
<i>Spica</i> ...	α Virginis.
<i>Sulaphat</i> ...	γ Lyræ.
<i>Svalocin</i> ...	α Delphini.
<i>Talitha, Talita</i> ...	ι Ursæ Majoris.
<i>Tarazed</i> ...	γ Aquilæ.
<i>Taygeta</i> (a Pleiad) ...	19 Tauri.
<i>Thuban</i> ...	α Draconis.
<i>Unukalhay</i> (Cor } α Serpentis.	
Serpentis) }	
<i>Vega, Wega</i> ...	α Lyræ.
<i>Vindemiatrix</i> ...	ϵ Virginis.
<i>Wasat</i> ...	δ Geminorum.
<i>Yed</i> ...	δ Ophiuchi.
<i>Zaurak</i> ...	γ^1 Eridani.
<i>Zawijah, Zavijava</i> β Virginis.	
<i>Zosca, Zosma</i> ...	δ Leonis.
<i>Zuben el Genubi</i> ...	α Libræ.
<i>Zuben el Hakrabi</i> ...	γ Libræ.
<i>Zubenesch, Zuben el</i> } β Libræ	
Chamali, Zubenelg }	

INDEX TO THE CONSTELLATIONS.

With the number of the Map in which each is shown, and the approximate date of culmination of its central hour of Right Ascension at 9 p.m. and Midnight.

For each Hour later or earlier than 9 a.m. or midnight—

Earlier—Add 15 days to dates given below.

Later—Subtract 15 days from „ „

For each Week later or earlier than dates below—

Earlier—Add 28 minutes to 9 p.m. or midnight

Later—Subtract „ from „ „

Name of Constellation	Genitive.	See Map No.	Approx. Date Culmination 9 p.m.	Approx. Date Culmination Midnight.	Name of Constellation.	Genitive.	See Map No.	Approx. Date Culmination 9 p.m.	Approx. Date Culmination Midnight.
ANDROMEDA	Andromedæ	3	Nov. 15	Oct. 1	INDUS† ...	Indi	14, 15	Sept. 26	Aug. 12
ANTLIA† ...	Antliæ	8	Apr. 10	Feb. 24	LACERTA† ...	Lacertæ	3	Oct. 14	Aug. 30
APUS† ...	Apodis	16	June 30	May 16	LEO ...	Leonis	9	Apr. 15	Mar. 1
AQUARIUS	Aquarii	4	Oct. 7	Aug. 23	LEO MINOR†	Leonis Minoris	9	Apr. 12	Feb. 26
AQUILA ...	Aquilæ	13	Aug. 30	July 16	LEPUS ...	Leporis	6	Jan. 29	Dec. 15
ARA ...	Aræ	12	July 22	June 7	LIBRA ...	Libræ	12	June 25	May 11
ARGO ...	Argûs	8	Mar. 11	Jan. 25	LUPUS ...	Lupi	12	June 19	May 5
ARIES ...	Arietis	5	Dec. 12	Oct. 28	LYNX† ...	Lyncis	1, 7	Mar. 5	Jan. 19
AURIGA ...	Aurigæ	5	Feb. 2	Dec. 19	LYRA ...	Lyræ	13	Aug. 18	July 4
BOÖTES ...	Boötis	11	June 12	Apr. 28	MALUS† (ARGO) ...	Mali	8	Mar. 19	Feb. 2
CAELUM† ...	Cæli	6	Jan. 13	Nov. 29	MENSA† ...	Mensæ	15, 16	Feb. 3	Dec. 20
CAMELOPARDUS†	Camelopardi	1, 2	Jan. 31	Dec. 17	MICROSCOPIUM†	Microscopii	14	Sept. 19	Aug. 5
CANCER ...	Canceri	7	Mar. 12	Jan. 26	MONOCEROS†	Monocerotis	7, 8	Feb. 22	Jan. 8
CANES VENATICI†	Canum Venaticorum	9	May 21	Apr. 6	MUSCA† ...	Muscæ	16	May 14	Mar. 30
CANIS MAJOR	Canis Majoris	8	Feb. 13	Dec. 30	NORMA† ...	Normæ	12	July 6	May 22
CANIS MINOR	Canis Minoris	7	Feb. 27	Jan. 13	OCTANS† ...	Octantis	15, 16	Circumpolar	
CAPRICORNUS	Capricorni	14	Sept. 19	Aug. 5	OPHIUCHUS	Ophiuchi	11, 12	July 25	June 10
CARINA† (ARGO) ...	Carinæ	8, 16	Mar. 16	Jan. 30	ORION ...	Orionis	5, 6	Jan. 23	Dec. 9
CASSIOPEIA	Cassiopeiæ	2, 3	Nov. 20	Oct. 6	PAVO† ...	Pavonis	15	Aug. 24	July 10
CENTAURUS	Centauri	10	May 25	Apr. 10	PEGASUS ...	Pegasi	3	Oct. 15	Aug. 31
CEPHEUS ...	Cephei	2	Oct. 10	Aug. 26	PERSEUS ...	Persei	5	Dec. 21	Nov. 6
CETUS ...	Ceti	4, 5	Nov. 30	Oct. 16	PHOENIX†	Phœnicis	4	Nov. 9	Sept. 25
CHAMÆLEON†	Chamæleontis	16	Apr. 13	Feb. 27	PICTOR† ...	Pictoris	6	Jan. 29	Dec. 15
CIRCINUS†	Circini	12, 16	June 24	May 10	PISCES ...	Piscium	3	Nov. 12	Sept. 28
COELUM† (CAELUM)	Cœli	6	Jan. 13	Nov. 29	PISCIS AUSTRALIS	Piscis Australis	4	Sept. 30	Aug. 16
COLUMBA†	Columbæ	6	Jan. 31	Dec. 17	PUPPIS† (ARGO) ...	Puppis	8	Feb. 26	Jan. 12
COMA BERENICES†	Comæ Berenices	9	May 17	Apr. 2	PYXIS† (See MALUS)	Reticuli	15	Jan. 4	Nov. 20
COROLLA (Corona Australis)	Corollæ	14	Aug. 12	June 28	RETICULUM†	...	13	Aug. 31	July 17
CORONA AUSTRALIS	Coronæ Australis				SAGITTA ...	Sagittæ	14	Aug. 20	July 6
CORONA BOREALIS	Coronæ Borealis	11	July 2	May 18	SAGITTARIUS	Sagittarû	12	July 10	May 26
CORVUS ...	Corvi	10	May 13	Mar. 29	SCORPIO ...	Scorpii	4	Nov. 14	Sept. 30
CRATER ...	Crateris	10	Apr. 28	Mar. 14	SCULPTOR†	Sculptoris	13	Aug. 12	June 28
CRUX†	Crucis	16	May 14	Mar. 30	SCUTUM† *	Scuti	11	July 21	June 6
CYGNUS ...	Cygni	13	Sept. 10	July 27	SERPENS ...	Serpentis	9, 10	Apr. 9	Feb. 23
DELPHINUS	Delphini	13	Sept. 15	Ang. 1	SEXTANS† ...	Sextantis	5	Jan. 15	Dec. 1
DORADO†	Doradûs	15, 16	Jan. 17	Dec. 3	TAURUS ...	Tauri	13	Aug. 9	June 25
DRACO ...	Draconis	1, 2	July 10	May 26	(TAURUS PONIATOWSKII)†	...	14	Aug. 14	June 30
EQUULEUS	Equulei	13	Sept. 21	Aug. 7	TELESCOPIUM†	Telescopii	15	Oct. 30	Sept. 15
ERIDANUS ...	Eridani	6	Jan. 2	Nov. 18	TOUCAN†	Toucanis	16	July 4	May 20
FORNAX†	Fornacis	6	Dec. 12	Oct. 28	TRIANGULUM }	Trianguli	3	Dec. 5	Oct. 21
GEMINI ...	Geminorum	7	Feb. 20	Jan. 6	AUSTRALIS† }	Australis	1, 9	Apr. 21	Mar. 7
GRUS†	Gruis	4	Oct. 9	Aug. 25	TRIANGULUM	Trianguli	1	June 25	May 11
HERCULES	Herculis	11	July 21	June 6	URSA MAJOR	Ursæ Majoris	8	Mar. 29	Feb. 12
HOROLOGIUM†	Horologii	6, 15	Dec. 20	Nov. 5	URSA MINOR	Ursæ Minoris	9, 10	May 25	Apr. 10
HYDRA ...	Hydræ	7, 10	Apr. 30	Mar. 16	VELA† (ARGO) ...	Velorum	16	Mar. 1	Jan. 15
HYDRUS†	Hydri	15	Dec. 14	Oct. 30	VIRGO ...	Virginis	13	Sept. 8	July 25
					VOLANS† ...	Volantis			
					VULPECULA†	Vulpeculæ			

* This constellation (Scutum Sobieskii) now recognised by the Internat. Astr. Union, denotes the lower corner of Aquila adjoining the tail of Serpens. It extends from about R.A. 18h. to 18h. 56m., and from Dec. 2° S. to 16° S. $\alpha=1$ Aquilæ; $\beta=6$ Aquilæ; $\gamma=B.A.C. 6279$; $\delta=2$ Aquilæ; $\epsilon=3$ Aquilæ; $\eta=9$ Aquilæ. † TAURUS PONIATOWSKII is another small modern asterism. It is situated in the region bordering Hercules between Aquila and Ophiuchus, where some stars form the letter V. † Constellations so marked are modern.

SOUTHERN INDEX MAP

